
1100 वो.ए.सी. एवं 1500 वो.डी.सी. तक
एवं सहित कार्यकारी वोल्टता में अग्नि द्वारा
प्रभावित हो, धूयें एवं संक्षारी गैसों के अल्प
उत्सर्जन वाली, स्थिर संस्थापन में फॉयर
सर्वाइकल केवल, थर्मोसेटिंग इंसुलेटिड विशिष्टि
भाग 1 कवच वाली केबलों के लिए आवश्यकताएँ

**Specification for Thermosetting
Insulated Fire Survival Cables
for Fixed Installation having Low
Emission of Smoke and Corrosive
Gases when affected by Fire for
Working Voltages upto and including
1100 V A.C and 1500 V D.C**

Part 1 Requirements for Armoured Cables

ICS 29.060.20

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Power Cable Sectional Committee had been approved by the Electro technical Division Council.

This standard covers the requirements of thermosetting insulated cables with circuit integrity when affected with fire. The cables in this specification are rated for up to and including nominal voltage of 1 100 V a.c. and 1 500 V d.c. These cables may be used in places in/near confined areas, such as high-rise buildings, power stations, hospitals, malls or important installations etc. where safe evacuation of personnel in case of a fire is essential, as per guidelines of National Building Code, while maintaining the essential electrical services for a defined period of time. The recommended current rating and required derating factors shall be as per IS 3961 (Part 6). Few applications of fire survival cables are given in Annex A for information.

This part of the standard covers armoured cable. The requirements for multicore unarmoured and screened cables are covered in Part 2 of this standard (*under preparation*)

This standard has following five sections:

Section I	General
Section II	Materials
Section III	Construction
Section IV	Tests
Section V	Identification, packing and marking

While formulating this draft standard, considerable assistance has been drawn from the following:

IEC 60331-1 : 2018 Tests for electric cables under fire conditions — Circuit integrity — Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0.6/1.0 kV and with an overall diameter exceeding 20 mm.

IS/IEC 60371-3-8 Specification for Insulating material based on mica.

The composition of the Committee responsible for the formulation of this standard is given at Annex G.

Indian Standard

SPECIFICATION FOR THERMOSETTING INSULATED FIRE SURVIVAL CABLES FOR FIXED INSTALLATION HAVING LOW EMISSION OF SMOKE AND CORROSIVE GASES WHEN AFFECTED BY FIRE FOR WORKING VOLTAGES UPTO AND INCLUDING 1100 V A C AND 1500 V D C

PART 1 REQUIREMENTS FOR ARMoured CABLES

SECTION I GENERAL

1 SCOPE

This Indian Standard covers the requirements of thermosetting insulated armoured fire survival cables for fixed installations having low emission of smoke and corrosive gasses for maintaining circuit integrity when affected by fire for single phase and three phase systems, suitable for operation at voltages up to and including 1 100 V a.c. and 1 500 V d.c.

These cables are suitable for use where combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 90 °C under normal operation and 250 °C under short circuit conditions.

NOTES

1 The cables conforming to this standard may be operated continuously at a power frequency voltage 10 percent higher than rated voltage.

2 The standard does not cover single core unarmoured unsheathed cable.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below:

<i>IS No.</i>	<i>Title</i>	<i>IS No.</i>	<i>Title</i>
3975 : 1999	Low carbon galvanized steel wires, formed wires and tapes for armoring of cables — Specification (<i>third revision</i>)	4826 : 1979	Specification for hot-dipped galvanized coatings on round steel wires (<i>first revision</i>)
4905 : 2015/ISO 24153 : 2009	Random sampling and randomization procedures (<i>first revision</i>)	7098 (Part 1) : 1988	Specification for crosslinked polyethylene insulated PVC sheathed cables: Part 1 For working voltages up to and including 1 100 Volts (<i>first revision</i>)
8130 : 2013	Conductors for insulated electric cables and flexible cords — Specification (<i>second revision</i>)	10462 (Part 1) : 1983	Fictitious calculation method for determination of dimensions of protective coverings of cable: Part 1 Elastomeric and thermoplastic insulated cables
10810 (Part 0) : 1984 (Part 1) : 1984 (Part 5) : 1984 (Part 6) : 1984	Methods of test for cables: General Annealing test for wires used as conductors Conductor resistance test Thickness of thermoplastic and elastomeric insulation and sheath	1885 (Part 32) : 2019	Electrotechnical vocabulary: Part 32 Electric cables (<i>second revision</i>)
3961 (Part 6) : 2016	Recommended current ratings for cables: Part 6 Cross-linked polyethylene insulated PVC sheathed cables		

<i>IS No.</i>	<i>Title</i>
(Part 7) : 1984	Tensile Strength and elongation at break of thermoplastic and elastomeric insulation and sheath
(Part 11) : 1984	Thermal ageing in air
(Part 12) : 1984	Shrinkage test
(Part 13) : 1984	Ozone resistance test
(Part 30) : 1984	Hot set test
(Part 31) : 1984	Oil resistance test
(Part 36) : 1984	Dimensions of armoring material
(Part 37) : 1984	Tensile strength and elongation at break of armoring materials
(Part 38) : 1984	Torsion test on galvanized steel wires for armoring
(Part 39) : 1984	Winding test on galvanized steel strips for armoring
(Part 40) : 1984	Uniformity of zinc coating on steel armour
(Part 41) : 1984	Mass of zinc coating on steel armour
(Part 42) : 1984	Resistivity test of armour wires and strips and conductance test of armour (wires/strips)
(Part 43) : 1984	Insulation resistance
(Part 45) : 1984	High voltage test
(Part 53) : 1984	Flammability test
(Part 58) : 1998	Oxygen index test
(Part 59) : 1988	Determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables
(Part 61) : 1988	Flame retardant test
(Part 62) : 1993	Flame retardant test for bunched cables
(Part 63) : 1993	Measurement of smoke density of electric cables under fire Conditions
(Part 64) : 2003	Measurement of temperature index

3 TERMINOLOGY

For the purpose of this Standard, in addition to the definitions given in IS 1885 (Part 32), the following shall apply.

3.1 Routine Tests — Tests made by the manufacturer on all finished cable lengths to demonstrate the integrity of the cable under fire conditions.

3.2 Type Tests — Tests required to be made before supply on a general commercial basis a type of cable in order to demonstrate satisfactory performance characteristics to meet the intended application.

NOTE — These tests are of such nature that they need not be repeated unless changes are made in the cable materials or design which might change the performance characteristics of cable.

3.3 Acceptance Tests — Tests carried out on samples taken from a lot, for the purpose of acceptance of the lot.

3.4 Optional Tests — Special tests to be carried out, when required, by agreement between the purchaser and the supplier.

3.5 Fire Survival Categories — Following categories of fire survival cable shall be applicable:

- | | | | |
|----|--|---|------------|
| a) | <i>Resistance to fire alone</i> | 950 °C for 3 h | Symbol F |
| b) | <i>Resistance to fire and water</i> | 650 °C for 15 min followed by 5 bursts for water | Symbol W |
| c) | <i>Resistance to fire and mechanical shock</i> | 950 °C for 15 min along with 03 mechanical impact | Symbol S |
| d) | <i>Resistance to fire, water and shock</i> | Category F3/F30/F60/F120 as below | Symbol FWS |

Category F 3: Resistance to fire, resistance to fire with water, resistance to fire with mechanical shock, assessed separately when tested in accordance to **E-7.3**, **E-7.4** and **E-7.5** respectively.

Category F 30: Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 30 min

Category F60: Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 60 min

Category F120: Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 120 min

SECTION II MATERIALS

4 CONDUCTORS

The conductors shall be composed of annealed plain/tinned copper wires and shall conform to IS 8130.

5 TAPE

The manufacturer shall have the option to apply single tape or multiple layers/types of tapes under and/or over the insulation in order to meet the circuit integrity requirements under fire conditions. These tapes shall not be considered as part of the insulation. Tapes shall have minimum thickness of 0.10 mm. Following types or any other suitable type of tapes shall be used to meet the temperature requirements of fire survival categories:

- a) Glass mica tape
- b) Polyethylene terephthalate (PETP); and
- c) Fiber glass tape (FGT).

6 INSULATION

The insulation shall be XLPE or XL-HFFR confirming to the requirements given in Table 1.

7 FILLERS AND INNER SHEATH

7.1 The fillers and inner sheath shall be of the following:

- a) Vulcanized or unvulcanized rubber, or
- b) Thermoplastic materials.

7.2 Vulcanized or unvulcanized rubber, or thermoplastic material used for inner sheath shall not be harder than insulation and outer sheath respectively. Fillers and inner sheath materials shall be Flame retardant type and shall be compatible with temperature rating of the cable and shall have no deleterious effect on any other component of the cable.

8 ARMOUR

Armour shall consist of Galvanized round steel wire conforming to the requirements of IS 3975.

9 OUTER SHEATH

The outer sheath shall consist of zero halogen sheathing grade HFS-TP 90 or HFS-XL 90 compound meeting the requirements given in Table 2.

SECTION III CONSTRUCTION

10 CONDUCTORS

10.1 The construction of the conductor shall be as follows:

Nominal Cross-section (in mm ²)	Solid/Stranded	Flexibility Class (IS 8130)
1.5 to 6	Solid/Stranded	1 for solid 2 for stranded
10 and above	Stranded	2

10.2 Glass mica tape(s) shall be applied over conductor with adequate overlap. Polyethylene Terephthalate tape may be applied over the glass mica tape at the discretion of the manufacturer.

10.3 Cables with reduced neutral conductor shall have sizes as given in Table 3.

11 INSULATION

11.1 The taped conductor shall be provided with cross-linked Polyethylene/XL-HFFR insulation applied by extrusion.

11.2 Thickness of Insulation

The average thickness of insulation shall be not less than the nominal value specified in Table 4.

11.3 Tolerance on Thickness of Insulation

The smallest of measured values of thickness of insulation shall not fall below the nominal value (t_i) specified in Table 4 by more than $(0.1 \text{ mm} + 0.1 t_i)$.

11.4 Application of Insulation

The insulation shall be so applied that it fits closely on the conductor (or barrier if any) and it shall be possible to remove it without damaging the conductor.

12 CORE IDENTIFICATION

12.1 Cores shall be identified as specified below:

- a) Colored strip applied on the core (*see* Note 1) or
- b) Coloring of insulation as follows:

1 core: red, black, yellow, blue or natural

2 core: red and black

- 3 core: red, yellow and blue
- 4 core: red, yellow, blue and black
- 5 core: red, yellow, blue, black and grey
- 6 core and above: two adjacent cores (counting and direction core) in each layer blue and yellow, remaining cores, grey;

c) By numerals either by applying numbered strips or by printing on the cores as follows (*see* Note 2):

- 2 core: 0 and 1
- 3 core: 0, 1 and 2
- 4 core: 0, 1, 2 and 3

NOTES

1 For identification by using coloured strips, red, yellow and blue colours shall be used to identify the phase conductors, and black to identify reduced neutral conductor.

2 Identification by numerals is applicable up to 4 core cables. For control cables, numerals 0 and 1 shall be adopted for counting core and direction core respectively: remaining core shall not be numbered.

12.2 For reduced neutral conductors the core shall be black.

12.3 For cables having more than 5 cores, as an alternate to the provisions of **12.1**, the core identification may be done by numbers. In that case, the insulation of cores shall be of the same colour and numbered sequentially starting by number 1 in the inner layer. The numbers shall be printed in Hindu-Arabic numerals on the outer surface of the cores. All the numbers shall be of the same colour, which shall contrast with the colour of the insulation. The numerals shall be legible.

12.4 For reduced neutral conductors, the core shall have '0' number.

13 LAYING UP OF CORES

The cores shall be laid up with a suitable lay. The outer most layer shall have right hand lay and the successive layers shall be laid with opposite lay. Wherever necessary, the interstices shall be filled with non-hygroscopic material to provide reasonable circularity of laid up cable. The recommended plan for lay cores is given in Table 5.

A fibre glass binder tape may be applied over laid up cores. It shall be possible to remove fillers and binder tape (if any) from the cable without damaging the insulation of cores.

14 INNER SHEATH

14.1 The laid up core shall be provided with an inner sheath applied by extrusion in such a way that it fits closely on laid-up and it shall be possible to remove it without any damage to the insulation.

14.2 Thickness of Inner Sheath

The average thickness of inner sheath shall be not less than the nominal value (t_b) given in Table 6.

14.3 A fibre glass tape may be applied over the inner sheath at the discretion of the manufacturer.

14.4 Tolerance on Thickness of Inner Sheath

The smallest measured values of thickness of inner sheath shall not fall below the nominal values (t_b) specified in Table 6 by more than $(0.2 \text{ mm} + 0.2 t_b)$.

15 ARMOURING

15.1 Application

15.1.1 Armouring shall be applied over the insulation in case of single core cables and over inner sheath in case of twin, three and multi-core cables.

15.1.2 The armour wires shall be applied as closely as possible with a coverage of not less than 90 percent. The coverage shall be done as per Annex B.

15.1.3 The direction of lay of the armour shall be left handed. For double wire armoured cables, this requirement shall apply to the inner layer of wires. The outer layer shall, except in special cases, be applied in the reverse direction to the inner layer, and there shall be a separator of suitable non-hygroscopic material such as plastic tape, bituminized cotton tape, bituminized hessian tape, rubber tape or proofed tape between the inner and other layers of armour wires.

15.1.4 A binder tape may be provided on the armour.

15.2 Type of Armour

The armour shall consist of galvanized round steel wires only.

NOTE — It may be desirable for single core cables intended for use on ac systems to be armoured with non-magnetic material. Melting temperature of such non-magnetic material shall be equal or more than the fire rating of the cable.

15.3 Dimensions

The dimensions of galvanized steel wires shall be as specified in Table 7. The tolerance on nominal dimensions shall be as per IS 3975.

15.4 The round steel wires taken from the cable shall meet the following requirements.

- a) The tensile strength of round steel wire shall be not less than 250 N/mm² and not more 580 N/mm².
- b) The elongation at break of round steel wire shall be not less than 6 percent.
- c) Round steel wire shall meet the requirements of torsion test. The gauge length between vices and

the minimum number of turns without break shall be as per Table 6 of IS 3975.

- d) The uniformity of zinc coating of round steel wire shall comply with the requirements of IS 3975 subject to the minimum number of dips shall be reduced by one half-minute dip.
- e) The mass of zinc coating of round steel wire shall be not less than 95 percent of the mass specified in Table 2 of IS 4826.
- f) The resistivity of the round steel wire shall meet the requirements of IS 3975.

15.5 Joints

The joints in armour wire shall be made by brazing or welding and the surface irregularities shall be removed. A joint in any wire shall be at least 300 mm from the nearest joint in any other armour wire in the complete cable.

15.6 Resistance

15.6.1 If specified by the purchaser the resistance of the galvanized steel wire armour shall be measured. The result shall comply with appropriate values when corrected to 20 °C as given in Table 8.

15.6.2 In case of cable for the use in mines, the resistance of armour shall not exceed that of the conductor as specified in IS 8130 by more than 33 percent. To satisfy this, substitution of galvanized wires in armouring by required number of tinned copper wires is permissible.

16 OUTER SHEATH

16.1 The outer sheath shall be applied by extrusion. It shall be black or any other colour as agreed to between the purchaser and the supplier.

16.2 The average thickness of outer sheath shall be not less than nominal value (t_s) specified in Table 6.

16.3 The smallest of the measured values of thickness shall not fall below the nominal value (t_s) specified in Table 6 by more than $(0.2 \text{ mm} + 0.2 t_s)$.

SECTION IV TESTS

17 CLASSIFICATION OF TESTS

17.1 Type Tests

The tests given in Table 9 shall constitute type tests as applicable.

17.2 Acceptance Tests

17.2.1 The following shall constitute the acceptance tests:

- a) Annealing test (for copper);
- b) Conductor resistance test;

- c) Test for thickness of insulation and sheath;
- d) Tensile strength and elongation at break test of insulation and sheath;
- e) Hot set test for insulation and sheath (where applicable);
- f) High voltage test;
- g) Insulation resistance (volume resistivity) test; and
- h) Circuit integrity test under fire condition.

17.2.2 Recommended sampling plan for acceptance tests is given at Annex C. However, circuit integrity test under fire condition shall be conducted on one sample each for cable diameter up to and above 20 mm from the offered lot.

17.3 Routine Tests

The following shall constitute the routine tests:

- a) Conductor resistance test; and
- b) High voltage test.

18 DETAILS OF TESTS

18.1 General

Unless otherwise stated in this standard, the tests shall be carried out in accordance with appropriate part of IS 10810 (various parts) taking into account additional information given, if any, in this standard.

18.2 High Voltage Test

18.2.1 Type/Acceptance/Routine Test

High voltage test at room temperature: The cables shall withstand an a.c. voltage of 3 kV (rms) or a dc voltage of 7.2 kV between conductors, and between conductors and ECC (if any) for period of 5 min for each test connection.

18.3 Abrasion Resistance Test

The test shall be conducted according to Annex D. The outer sheath shall be deemed satisfactory provided that examination of the sample after conducting the test shall reveal no cracks or splits in the internal and external surfaces without magnification.

18.4 Circuit Integrity Test under Fire Condition

The cable shall meet the requirements specified in 3.5 and tested as per Annex E.

18.5 Flammability Test

18.5.1 Test on Single Cable

After the test, there shall be no visible damages on the test specimen within 300 mm from the upper end. Marks from fixing devices, soot or change of colour are not considered damages.

18.5.2 Test on Bunched Cables, Category – C

After burning has ceased, the cable should be wiped clean and the charred or effected portion should not have reached a height exceeding 2.5 m above the bottom edge of the burner, measured at the front rear end of the cable assembly. Other test category (for example, Category A or B) may be offered as per agreement between supplier and customer.

18.6 Oxygen Index Test

The test shall be conducted as per IS 10810 (Part 58), on samples at $(27 \pm 2) ^\circ\text{C}$.

The oxygen index shall not be less than 31.

NOTE — This test is not applicable for cable produced with crosslinked compounds.

18.7 Test for Temperature Index

The test shall be conducted as per IS 10810 (Part 64).

The minimum measured value of temperature index shall be $250 ^\circ\text{C}$ at which the oxygen index is 21.

NOTE — This test is not applicable for cable produced with crosslinked compounds.

18.8 Smoke Density

The test shall be conducted as per IS 10810 (Part 63).

The minimum transmittance of light shall be 70 percent.

18.9 Water Immersion Test (Effect of Water on Sheath)

This test represents the influence of water on the mechanical properties of sheath through tensile strength and elongation at break on untreated and treated samples after water immersion. The test results on the conditioned and unconditioned samples shall not have any significant change. The test samples are immersed into the de-ionized water for the temperature and duration as specified in Table 2. After the water immersion, the sample shall be cooled off to $(20 \pm 5) ^\circ\text{C}$ before taken out of water. The test samples are removed off the moisture using tissue paper and the tensile strength and elongation at break tests are conducted within 40 min as per IS 10810 (Part 7).

SECTION V IDENTIFICATION PACKING AND MARKING**19 IDENTIFICATION****19.1 Manufacturer's Identification**

The manufacturer shall be identified throughout the length of the cables by manufacturer's name or trademark being printed, indented or embossed on the outer sheath only. In case none of these methods are employed, or if purchaser so desires, coloured identification threads in accordance with a scheme to be approved by the Bureau of Indian Standards shall be employed.

19.2 Cable Identification

In order to distinguish fire survival cables from other cables, the word 'FS Cable with category' shall be indented, printed or embossed throughout the length of the cable. Also, the voltage grade of the cable shall be identified throughout the length of the cable by printing, embossing or indenting on the outer sheath or by means of a tape bearing the voltage grade of the cable (for example 1.1 KV or 1 100 V)

NOTE — For example, FS Cable FWS.

19.3 Sequential Length Marking

Sequential length marking shall be provided over the outer sheath at every metre by hot foil/printing/embossing.

19.4 Cable Code

The following code shall be used for designating the cable:

<i>Constituent</i>	<i>Code Letter</i>
Insulation	2X/Z (2X for XLPE and Z for XL-HFFR)
Steel round wire armour	W
Double steel round wire armour	WW
Outer sheath (HFS-TP 90 or HFS-XL 90)	H
Non magnetic round wire armour	Wa
Fire rating of cable	F3/F30/F60/F120

20 PACKING AND MARKING

20.1 The cable shall be wound on a drum (*see* IS 10418) and packed. The ends of the cable shall be sealed by means of non-hygroscopic sealing material.

20.2 The drum shall carry the following information either stenciled on it or contained in a label attached to it:

- Reference to this Indian Standard for example, *see* IS XXXXX;
- Manufacture's name, brand name or trademark;
- Type of cable and voltage grade;
- Number of cores;
- Nominal cross-sectional area of conductor;
- Cable code;
- Length of cable on the drum;
- Number of lengths on the drum (if more than one);

- j) Direction of rotation of drum (by means of an arrow) in case of packed wooden drums;
- k) Approximate gross mass;
- m) Country of manufacture; and
- n) Year of manufacture.

20.3 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act, 2016* and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

Table 1 Properties of Insulation
(Clause 6)

SI No.	Property	XLPE	XL – HFFR
(1)	(2)	(3)	(4)
i)	Tensile strength - Min.	12.5 N/mm ²	10 N/mm ²
ii)	Elongation at break - Min.	200 percent	125 percent
iii)	Ageing test in air oven		
	a) Treatment temperature/duration	135 ± 3 °C, 7 Days	135 ± 3 °C, 7 Days
	b) Tensile strength variation - Max.	± 25 percent	± 30 percent
	c) Elongation variation - Max.	± 25 percent	± 30 percent
iv)	Hot set test		
	a) Treatment temperature	200 ± 3 °C	200 ± 3 °C
	Time under load	15 min	15 min
	Mechanical stress	20 N/cm ²	20 N/cm ²
	b) Elongation under load - Max.	175 percent	100 percent
	c) Permanent elongation (set) after cooling - Max.	15 percent	15 percent
v)	Shrinkage		
	a) Treatment temperature/duration	130 ± 3 °C, 1 h	-
	b) Shrinkage - Max.	4 percent	-
vi)	Water absorption		
	Treatment temperature/duration	85 ± 2 °C, 14 Days	-
	Water absorption - Max.	1 mg/cm ²	-
vii)	Volume resistivity		
	At 27 °C - Max.	1 × 10 ¹⁴ ohm-cm	1 × 10 ¹⁴ ohm-cm
	At 90 °C - Max.	1 × 10 ¹² ohm-cm	1 × 10 ¹⁰ ohm-cm
viii)	Ozone resistance test		
	Treatment temperature /duration	-	25 ± 2 °C, 1 Days
	Concentration	-	(250 - 300) × 10 ⁻⁴ percent
	Result	-	No cracks
ix)	Assessment of halogen		
	a) pH	-	> 4.3
	b) Conductivity	-	< 10 µs/mm
	c) HCL and HBR	-	< 0.5 percent
	d) HF	-	< 0.1 percent

Table 2 Properties of Halogen Free Sheath
(Clauses 9, 18.9)

Sl No.	Test	Unit	Test Method	Type of Sheathing	
				HFS-TP 90	HFS-XL 90
1	General				
1.1	Rated temperature	°C	-	90	90
2	Properties before ageing				
2.1	Tensile strength - <i>Min.</i>	N/mm ²	IS 10810 (Part 7)	10	10
	Elongation At Break - <i>Min.</i>	percent		100	100
2.2	Properties after ageing in Air oven				
	Ageing condition				
	Temperature	°C	10810 (Part 11)	100 ± 2	100 ± 2
	Duration	Hours		168	168
	Tensile strength - <i>Min.</i>	N/mm ²	IS 10810 (Part 7)	10	10
	Variation - <i>Max.</i>	Percent	-	± 40	± 40
	Elongation at break - <i>Min.</i>	Percent	IS 10810 (Part 7)	100	100
	Variation - <i>Max.</i>	Percent	-	± 40	± 40
3	Hot deformation test				
	Temperature	°C	IS 10810 (Part 15)	90 ± 2	90 ± 2
	Duration	Hours		4	4
	Maximum indentation	Percent		50	50
4	Hot set test				
	Temperature	°C	IS 10810 (Part 30)	-	200 ± 3
	Duration	Minutes		-	15
	Mechanical Stress	N/cm ²		-	20
	Elongation under load - <i>Max.</i>	Percent		-	175
	Permanent (set) elongation- <i>Max.</i>	Percent		-	15
5	Heat shock test				
	Temperature	°C	IS 10810 (Part 14)	150 ± 2	-
	Duration	Hours		1	-
	Result	-		No crack	-
6	Cold bend test				
	Temperature	°C	IS 10810 (Part 20)	-15 ± 2	-15 ± 2
	Duration	Hours		3	3
	Result	-		No crack	No crack
7	Cold Impact Test				
	Temperature	°C	IS 10810 (Part 21)	-15 ± 2	-15 ± 2
	Duration	Hours		3	3
	Result	-		No crack	No crack
8	Effect of water on sheath (water immersion test)				
	Temperature	°C	18.9	70 ± 2	70 ± 2
	Duration	Hours		168	168
	Variation in tensile strength	Percent		± 30	± 30
	Variation in elongation at break	Percent		± 30	± 30

Table 2 (Concluded)

SI No.	Test	Unit	Test Method	Type of Sheathing	
				HFS-TP 90	HFS-XL 90
9	Assessment of halogen				
	a) pH	pH	Annex F	≥ 4.3	≥ 4.3
	b) Conductivity	$\mu\text{S}/\text{mm}$		≤ 10	≤ 10
	c) HCL and HBR	Percent		≤ 0.5	≤ 0.5
	d) HF	Percent		≤ 0.1	≤ 0.1
10	Ozone resistance test				
	Temperature	$^{\circ}\text{C}$	IS 10810 (Part 13)	25 ± 2	25 ± 2
	Duration	Hours		24	24
	Concentration	Percent		$250 \text{ to } 300 \times 10^{-4}$	$250 \text{ to } 300 \times 10^{-4}$
	Result	—		No crack	No crack

Table 3 Cross Sectional Area of Reduced Neutral Conductors
(Clause 10.3)

Nominal Cross Sectional Areas of Main Conductor	Cross Sectional Area of Reduced Neutral Conductor
(1) (mm^2)	(2) (mm^2)
25	16
35	16
50	25
70	35
95	50
120	70
150	70
185	95
240	120
300	150
400	185
500	240
630	300

Table 4 Insulation Thickness

(Clause 11.2 and 11.3)

Nominal Area of Conductor (mm ²)	XLPE Insulation		XL-HFFR	
	Single core Armoured Cables	Single Core Un-armoured and Multi-core Cables	Single core Armoured Cables	Single Core Unarmoured and Multi-core Cables
(1)	(2)	(3)	(4)	(5)
1.5	1.0	0.7	1.1	0.8
2.5	1.0	0.7	1.1	0.8
4	1.0	0.7	1.1	0.8
6	1.0	0.7	1.1	0.8
10	1.0	0.7	1.2	0.9
16	1.0	0.7	1.2	0.9
25	1.2	0.9	1.3	1.0
35	1.2	0.9	1.3	1.0
50	1.3	1.0	1.4	1.1
70	1.4	1.1	1.5	1.2
95	1.4	1.1	1.5	1.2
120	1.5	1.2	1.7	1.4
150	1.7	1.4	1.9	1.6
185	1.9	1.6	2.1	1.8
240	2.0	1.7	2.1	1.8
300	2.1	1.8	2.3	2.0
400	2.4	2.0	2.6	2.2
500	2.6	2.2	2.8	2.4
630	2.8	2.4	3.0	2.6

Table 5 Recommended Lay Up of Cores

(Clause 13)

Sl No.	No. of Cores	Lay-up	Sl No.	No. of Cores	Lay-up	Sl No.	No. of cores	Lay-up
i)	2	2	xxxv)	36	0-6-12-18	lxxix)	70	2-8-14-20-26
ii)	3	3	xxxvi)	37	1-6-12-18	lxx)	71	2-8-14-20-27
iii)	4	4	xxxvii)	38	1-6-12-19	lxxi)	72	2-8-14-21-27
iv)	5	5	xxxviii)	39	1-6-13-19	lxxii)	73	3-9-15-20-26
v)	6	6	xxxix)	40	1-7-13-19	lxxiii)	74	3-9-15-21-26
vi)	7	1-6	xxxx)	41	1-7-13-20	lxxiv)	75	3-9-15-21-27
vii)	8	1-7	xxxxi)	42	2-8-13-19	lxxv)	76	3-9-15-21-28
viii)	9	1-8	xxxxii)	43	2-8-14-19	lxxvi)	77	3-9-15-22-28
ix)	10	2-8	xxxxiii)	44	2-8-14-20	lxxvii)	78	4-10-15-21-28
x)	11	3-8	xxxxiv)	45	3-9-14-20	lxxviii)	79	4-10-16-22-27
xi)	12	3-9	xxxxv)	46	3-9-15-22	lxxix)	80	4-10-16-22-28
xii)	13	3-10	xxxxvi)	47	3-9-15-20	lxxx)	81	4-10-16-22-29
xiii)	14	4-10	xxxxvii)	48	3-9-15-21	lxxxi)	82	4-10-16-23-29
xiv)	15	5-10	xxxxviii)	49	3-9-15-22	lxxxii)	83	4-10-17-23-29
xv)	16	5-11	xxxxix)	50	3-9-16-22	lxxxiii)	84	5-11-17-23-28
xvi)	17	5-12	xxxxx)	51	4-10-16-21	lxxxiv)	85	5-11-17-23-29

Table 5 (Concluded)

SI No.	No. of Cores	Lay-up	SI No.	No. of Cores	Lay-up	SI No.	No. of cores	Lay-up
xvii)	18	0-6-12	li)	52	4-10-16-22	lxxxv)	86	5-11-17-23-30
xviii)	19	1-6-12	lii)	53	4-10-16-23	lxxxvi)	87	5-11-17-24-30
xix)	20	1-6-13	liii)	54	4-10-17-23	lxxxvii)	88	5-11-18-24-30
xx)	21	1-7-13	liv)	55	4-11-17-23	lxxxviii)	89	6-11-18-24-30
xxi)	22	2-7-13	lv)	56	5-11-17-23	lxxxix)	90	6-12-18-24-30
xxii)	23	2-8-13	lvi)	57	5-11-17-24	lxxxx)	91	1-6-12-18-24-30
xxiii)	24	2-8-14	lvii)	58	5-11-18-24	lxxxxi)	92	1-6-12-18-24-31
xxiv)	25	2-8-15	lviii)	59	5-12-18-24	lxxxxii)	93	1-6-12-18-25-31
xxv)	26	3-9-14	lix)	60	0-6-12-18-24	lxxxxiii)	94	1-6-12-19-25-31
xxvi)	27	3-9-15	lx)	61	1-6-12-18-24	lxxxxiv)	95	1-6-13-19-25-31
xxvii)	28	3-9-16	lxi)	62	1-6-12-18-25	lxxxv)	96	1-7-13-19-25-31
xviii)	29	4-10-15	lxii)	63	1-7-12-18-25	lxxxvi)	97	1-7-13-19-26-31
xxix)	30	4-10-16	lxiii)	64	1-7-13-18-25	lxxxvii)	98	2-8-13-19-25-31
xxx)	31	4-10-17	lxiv)	65	1-7-13-19-25	lxxxviii)	99	2-8-14-19-25-31
xxxi)	32	5-11-16	lxv)	66	1-7-13-19-26	lxxxix)	100	2-8-14-20-25-31
xxxii)	33	5-11-17	lxvi)	67	2-8-13-19-25			
xxxiii)	34	5-11-18	lxvii)	68	2-8-14-19-25			
xxxiv)	35	5-12-18	lxviii)	69	2-8-14-20-25			

NOTES

1 The figures indicate the number of cores in each successive layer. For example, 5-11-18 implies - 5 cores in the first, 11 cores in the second and 18 cores in the third layer, and so on.

2 This table is for guidance only.

Table 6 Thickness of Sheath
(Clauses 14.2, 14.4, 16.2 and 16.3)

SI No.	Calculated Diameter Over Core/Laid up Core (Ref IS 10462-1)		Thickness of Inner Sheath	Thickness of Outer Sheath
	Above (mm)	Up to and including (mm)	Nominal (mm)	Nominal (mm)
(1)	(2)	(3)	(4)	(5)
i)	-	10	0.8	1.6
ii)	10	15	1.0	1.8
iii)	15	20	1.0	2.0
iv)	20	25	1.0	2.0
v)	25	35	1.2	2.2
vi)	35	40	1.4	2.4
vii)	40	45	1.4	2.6
viii)	50	55	1.6	3.0
ix)	55	60	1.6	3.2
x)	60	65	1.8	3.4
xi)	65	70	1.8	3.6
xii)	70	75	1.8	3.8
xiii)	75	—	1.8	4.0

Table 7 Dimensions of Armour Round Wires
(Clause 15.3)

SI No.	Calculated Diameter under Armour [Ref to IS 10462 (Part 1)]		Diameter of Round Wire
	Above (mm)	Up to and including (mm)	Nominal (mm)
(1)	(2)	(3)	(5)
i)	-	10	0.9
ii)	10	13	1.4
iii)	13	25	1.6
iv)	25	40	2.0
v)	40	55	2.5
vi)	55	70	3.15
vii)	70	-	4.00

Table 8 Resistance of Armour Wire of Cables
(Clause 15.6.1)

SI No.	Nominal Area of Conductor (mm ²)	Maximum D.C. Resistance of Armour of Class At 20 °C			
		Two Core	Three Core	Four Core	Four Core with reduced neutral
		Round (Ω/km)	Round (Ω/km)	Round (Ω/km)	Round (Ω/km)
(1)	(2)	(3)	(4)	(5)	(6)
i)	1.5	6.71	6.35	5.82	—
ii)	2.5	6.07	5.73	5.24	—
iii)	4	5.45	5.14	4.69	—
iv)	6	4.91	4.63	4.21	—
v)	10	4.25	3.99	3.62	—
vi)	16	3.57	2.89	2.62	—
vii)	25	3.00	2.68	2.29	2.36
viii)	35	2.88	2.52	2.12	2.18
ix)	50	2.47	2.20	1.93	1.99
x)	70	2.15	1.49	1.24	1.29
xi)	95	1.53	1.31	1.12	1.18
xii)	120	1.38	1.17	1.01	1.12
xiii)	150	1.26	1.05	0.737	1.01
xiv)	185	1.14	0.767	0.652	0.715
xv)	240	0.791	0.675	0.590	0.625
xvi)	300	0.726	0.619	0.409	0.577
xvii)	400	0.627	0.428	0.377	0.384
xviii)	500	0.421	0.379	0.245	0.358
xix)	630	0.376	0.264	0.214	0.241

NOTES

1 The resistance of armour for single core cables has not been covered, since such cables are generally armoured with non-magnetic materials (see **15.2**).

2 The resistance of the armour may be measured at room temperature and corrected to 20 °C by means of correction factors given in IS 10810 (Part 42).

Table 9 Type Tests
(Clause 17.1)

SI No.	Tests	Requirements (Ref to IS No/Clause of this Standard)	Methods of Test, Ref to part of IS 10810
(1)	(2)	(3)	(4)
i)	Tests on conductor		
	a) Annealing test (for copper)	IS 8130	Part 1
	b) Conductor resistance test	IS 8130	Part 5
	c) Persulphate test for tinned conductor	IS 8130	Part 4
ii)	Test for armouring wires	Table 7 and IS 3975	Parts 36 to 42
iii)	Tests for thickness of insulation and sheath	11, 14, 16, Table 4 and Table 6	Part 6
iv)	Tests for insulation and Outer sheath:		
	a) Tensile strength and elongation at break before ageing	Table 1 and Table 2	Part 7
	b) Ageing in air oven	Table 1 and Table 2	Part 11
	c) Hot set test	Table 1 and Table 2	Part 30
	d) Shrinkage test	Table 1	Part 12
	e) Heat shock	Table 2	Part 14
	f) Cold bend	Table 2	Part 20
	g) Cold impact	Table 2	Part 21
	h) Water absorption (Gravimetric)	Table 1	Part 33
	j) Oxygen index test*	18.6	Part 58
	k) Temperature index test	18.7	Part 64
	m) Assessment of halogen (HCL)	Table 2	Annex F
	n) Smoke density	18.8	Part 63
	p) Ozone resistance	Table 1 and Table 2	Part 13
	q) Insulation resistance test	Table 1	Part 43
v)	Effect of water on sheath	Table 2	18.9
vi)	High voltage test	18.2	Part 45
vii)	Flammability test:		
	a) Flame test on single cable	18.5.1	Part 61
	b) Flame test on bunched cable	18.5.2	Part 62
viii)	Circuit integrity test under fire	18.4	Annex E
ix)	Abrasion resistance test	18.3	Annex D

* Not applicable for thermoset material.

NOTE — Insulation and sheath of the cable shall be tested for assessment of halogen which shall not exceed 0.5 percent when tested as per IS 10810 (Part 59).

ANNEX A

(Foreword)

APPLICATION OF FS CABLE

Sl No.	System Description	Cable Fire Rating Required (°C)	Time for which System Should Withstand (Minutes)
(1)	(2)	(3)	(4)
i)	Fire pumps	FS (950/FWS)	180
ii)	Pressurization	FS (950/FWS)	180
iii)	Smoke venting including its ancillary systems, such as dampers and actuators	950	60
iv)	Fire fighting shaft (staircase, lift, lift lobby)	FS (950/FWS)	180
v)	Fireman's lifts (including all lifts)	FS (950/FWS)	180
vi)	Exit signage lighting	950	120
vii)	Emergency lighting	950	120
viii)	Fire alarm system		
	a) Conventional (zone based system)	650	60
	b) Intelligent addressable system	650	60
ix)	Public address (PA) system (related to emergency voice evacuation and annunciation)	650	60
x)	Magnetic door hold open devices	650	60
xi)	Lighting in fire command centre and security room	FS (950/FWS)	180

ANNEX B

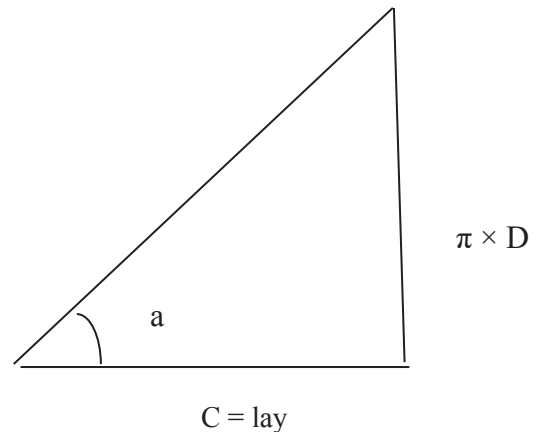
(Clause 15.1.2)

ARMOUR COVERAGE PERCENTAGE

$$\text{Percent Coverage} = \frac{N \times d}{W} \times 100$$

where

- N = number of parallel wires;
 d = diameter of wire/width of formed wires;
 W = $\pi \times D \times \cos a$;
 D = diameter under armour + thickness/diameter of armour
 a = angle between armouring wire/formed wires and axis of cable
 $\tan a = \pi \times D/C$; and
 C = lay length of armouring wires/formed wires



ANNEX C

(Clause 17.2.2)

SAMPLING OF CABLES**C-1 LOT**

In any consignment the cables of the same size and category manufactured under essentially similar conditions of production shall be grouped together to constitute a lot.

C-2 SAMPLING PLAN

C-2.1 Samples shall be taken and tested from each lot for ascertaining the conformity of the lot to the requirements of the specification.

C-2.2 The number of samples to be selected shall be as given below:

Number of Drums/Coils/Reels in the Lot	Number of Drums/Coils/Reels to be Taken as Sample	Permissible Number of Defectives
Up to 50	3	0
51-100	5	0
101-300	8	0
301 and above	13	1

C-2.3 These samples shall be taken at random. In order to ensure the randomness of selection, procedure given in IS 4905 may be followed.

C-3 NUMBER OF TESTS AND CRITERION FOR CONFORMITY

From each of the drum/coil/reels selected, suitable lengths of test samples shall be taken. The test samples shall be subjected to each of the acceptance tests. A test sample is called defective, if it fails in any one of the acceptance tests. If the number of defectives is less than or equal to the corresponding permissible number given in **C-2.2**, the lot shall be declared as conforming to the requirements of acceptance tests; otherwise not.

ANNEX D

(Clause 18.3 and Table 9)

ABRASION RESISTANCE TEST

D-1 The sample of cable shall be laid out straight and horizontal on a firm base. In the middle of the sample and perpendicular to it, a length of mild steel angle shall be placed horizontally, at right angles to the cable, with its angle edge resting on the cable and its arms symmetrical about the vertical plane through the longitudinal axis of the cable. The outer radius of curvature of the angle edge shall be not less than 1 mm and not greater than 2 mm (see Fig. D-1).

The steel angle shall be vertically loaded above the point of contact, with a force in accordance with Table 10.

The steel angle shall be dragged horizontally along the cable for a distance not less than 600 mm at a speed of between 150 mm/s and 300 mm/s. The direction of movement shall be reversed at the end of each pass to give 50 passes, 25 in each direction over the 600 mm test path.

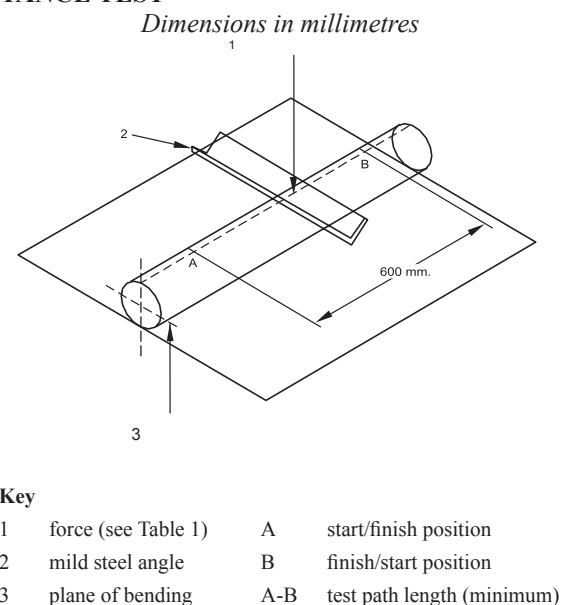


FIG. D-1 ABRASION TEST

Table 10 Vertical Force on Steel Angle
(Clause)

Overall Measured Diameter of Cable mm		Force N
Above and including	Up to	
30	40	65
40	50	105
50	60	155

Overall Measured Diameter of Cable mm		Force N
Above and including	Up to	
60	70	210
70	80	270
80	90	340
90	100	420
100	110	500
110 and above		550

ANNEX E

[Clauses 3.5, 18.4 and Table 9 (ix)]

TESTS FOR ELECTRIC CABLES UNDER FIRE CONDITIONS — CIRCUIT INTEGRITY

E-1 SCOPE

This annexure specifies the test method for cables which are required to maintain circuit integrity when subject to fire and mechanical shock and water jet under specified conditions.

This document includes details for the specific point of failure, continuity checking arrangement, test sample, test procedure relevant to electric power and control cables with rated voltage up to and including 1100 V a.c and 1500 V d.c.

CAUTION — The test given in this standard may involve the use of dangerous voltages and temperatures. Suitable precautions should be taken against the risk of shock, burning, fire and explosion that may be involved, and against any noxious fumes that may be produced.

E-2 NORMATIVE REFERENCES

The following International Standards are referred in the text in such a way that some or all of their content constitutes requirements of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced standard (including any amendments) applies:

IEC 60584-1 Thermocouples — Part 1: EMF specifications and tolerances

IEC 60269-3 Low-voltage fuses — Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) — Examples of standardized systems of fuses A to F

E-3 TERMS AND DEFINITIONS

For the purposes of this standard, the following terms and definitions apply.

E-3.1 Circuit Integrity — Ability of an electric cable to continue to operate in a designated manner whilst subjected to a specified flame source for a specified period of time under specified conditions.

E-3.2 Draught-free Environment — Space in which the results of tests are not significantly affected by the local air speed.

E-4 TEST ENVIRONMENT

The test shall be carried out in a draught-free environment within a suitable chamber, of minimum volume 20 m³, with facilities for disposing of any noxious gases resulting from the burning. Sufficient ventilation shall be available to sustain the flame for the duration of the test. Air inlets and the exhaust chimney should be located in such a way that the burner flame remains stable during the verification procedure and test. If necessary, the burner shall be shielded from any draughts by the use of draught shields. Windows may be installed in the walls of the chamber in order to observe the behavior of the cable during the test. Fume exhaust should be achieved by means of natural draught through a chimney located at least 1m from the burner. A damper may be used for adjustment of ventilation conditions.

NOTE — Experience has shown a chamber similar to the “3 m cube” specified in IEC 61034-1 to be suitable.

The chamber and test apparatus shall be at a temperature of between 10 °C and 40 °C at the start of each test.

The same ventilation and shielding conditions shall be used in the chamber during both the verification and cable test procedures.

E-5 TEST APPARATUS

E-5.1 Test Equipment

The test equipment shall consist of the following:

- a) for cables with overall diameter exceeding 20 mm, a test ladder comprising a steel framework fastened to a rigid support on to which the test specimen is mounted as described in E-5.2.

For cable with overall diameter upto and including 20 mm, a test wall comprising a board manufactured from heat-resistant and non-combustible material suitable for the temperature involved fastened to steel supports and mounted on a rigid support onto which the test specimen is mounted as described in E-5.2;

- b) a source of heat comprising a horizontally mounted ribbon burner as described in E-5.3;
 c) a shock-producing device as described in E-5.4;
 d) water jet device as described in E-5.5;
 e) a test wall equipped with thermocouples for verification of the source of heat as described in E-5.6;
 f) a continuity checking arrangement as described in E-5.7; and
 g) fuses as described in E-5.8.

A general arrangement of the test equipment are shown in Fig. E-1; Fig. E-2; Fig. E-3 and Fig. E-4.

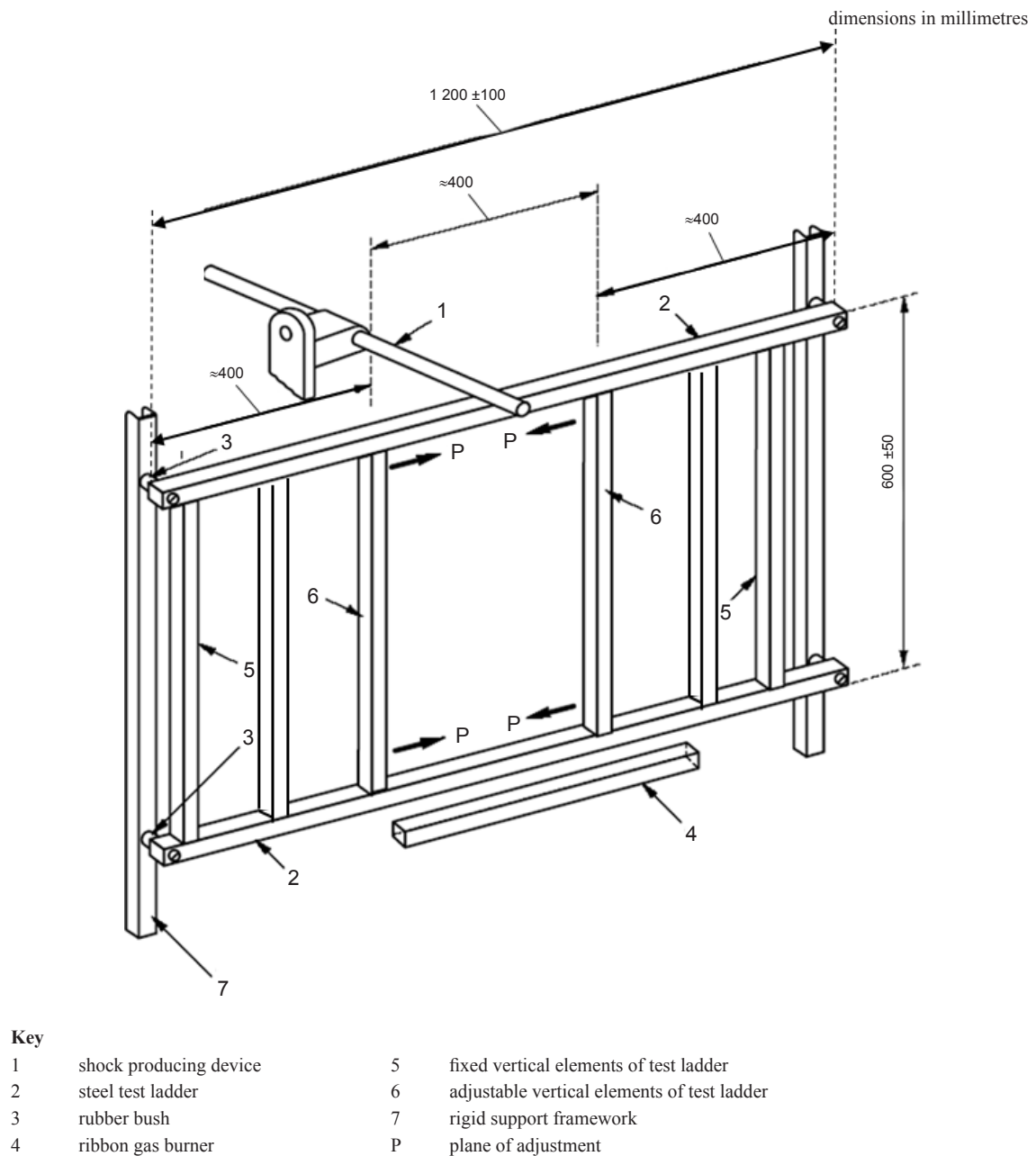


FIG. E-1 SCHEMATIC DIAGRAM OF TEST CONFIGURATION (DIAMETER > 20 MM)

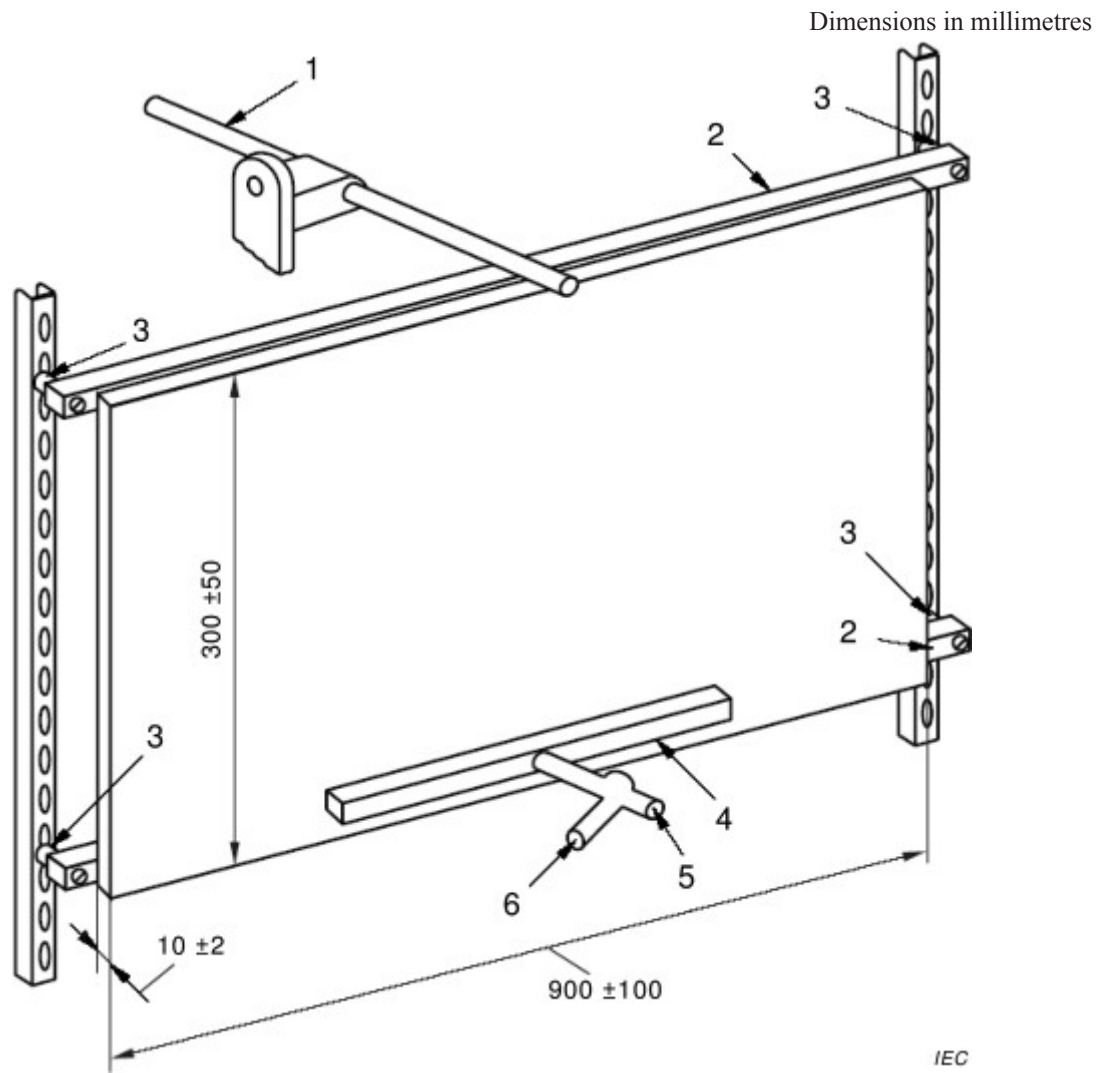
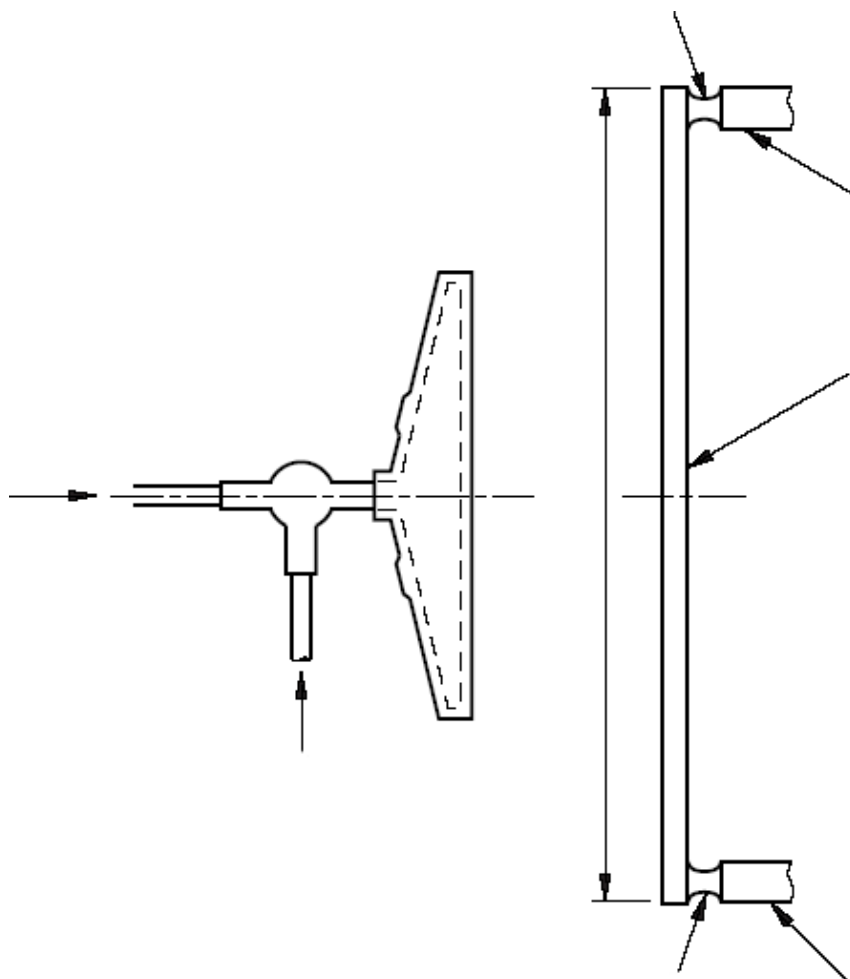


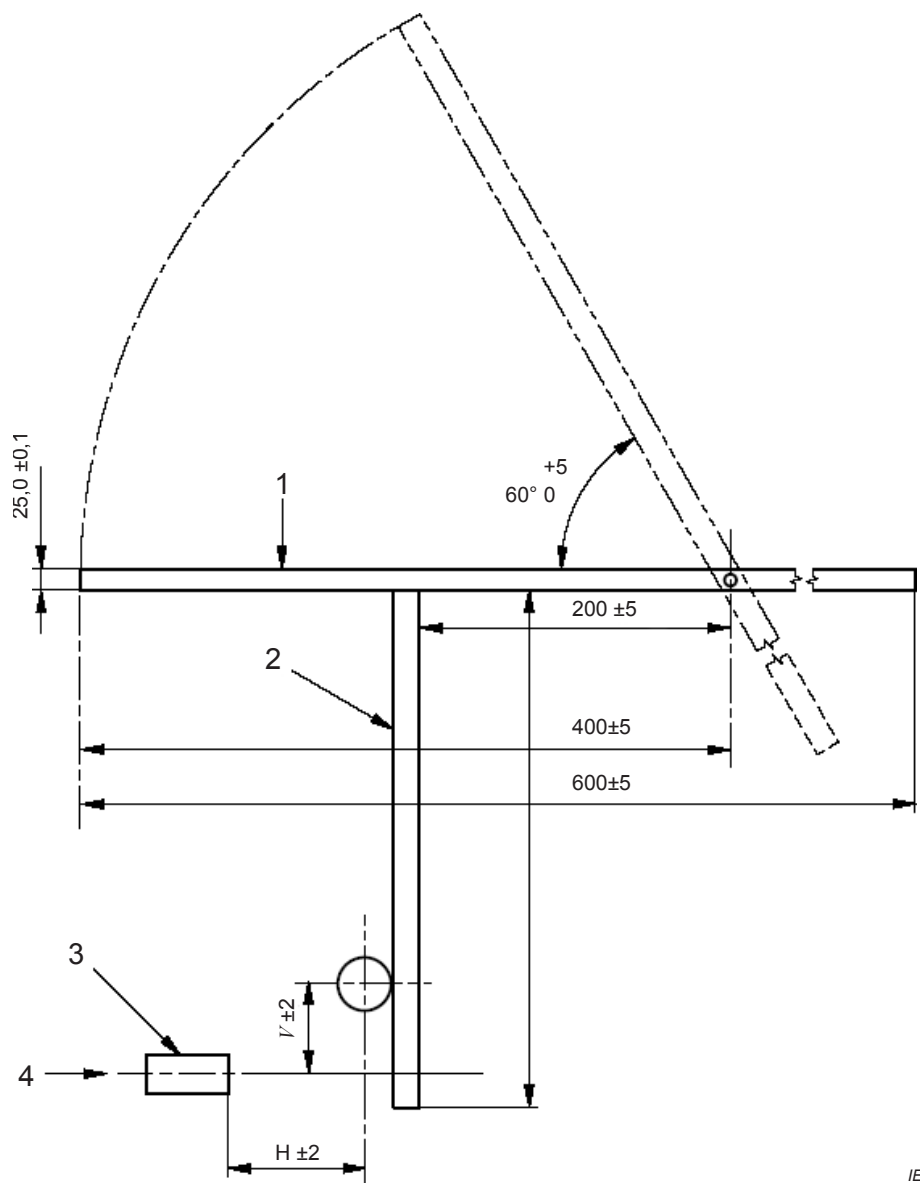
FIG. E-2 – SCHEMATIC DIAGRAM OF TEST CONFIGURATION (DIAMETER ≤ 20 MM)

Dimensions in millimetres

**Key**

- | | | | |
|---|-------------------------|---|------------------------------|
| 1 | entry for air | 4 | horizontal steel test ladder |
| 2 | rubber bush | 5 | entry for LPG gas |
| 3 | rigid support framework | | |

FIG. E-3 PLAN VIEW OF FIRE TEST EQUIPMENT



Key

1	shock producing device	H	horizontal distance from burner face to the centre of the test specimen
2	steel test ladder	V	vertical distance from centre line of burner to the centre of the test specimen
3	gas burner		
4	centre line of burner face		

FIG. E-4 END ELEVATION OF FIRE TEST EQUIPMENT (NOT TO SCALE)

E-5.2 Test Ladder and Mounting

The test ladder shall consist of a steel framework as shown in Fig. E-1 and Fig. E-2. The four central vertical elements of the ladder shall be adjustable in order to accommodate different sizes of cable under test. For cable whose diameter exceeding 20 mm the test ladder shall be ($L = 1200 \pm 100$) mm long and ($M = 600 \pm 50$) mm high, and the total mass of the test ladder shall be (24 ± 1) kg. For cable whose diameter not exceeding 20 mm the test ladder shall be ($L = 900 \pm 100$) mm long and ($M = 300 \pm 50$) mm high, and the total mass of the test wall shall be (10 ± 0.5) kg. Ballast, if required, shall be placed on the steel supports.

Each horizontal element shall have a mounting hole not more than 200 mm from each end for the cable whose diameter is exceeding 20 mm and 100 mm from each end for the cable whose diameter is not exceeding 20 mm, the exact position and diameter being determined by the particular supporting bush and supporting framework used. The test ladder shall be fastened to a rigid support by four bonded rubber bushes of hardness 50–60 Shore A fitted between the horizontal steel elements of the ladder and the support framework, as shown in Fig. E-1; Fig. E-2 and Fig. E-3 so as to allow movement under impact.

NOTES

- 1 Angle iron approximately 45 mm wide and 6 mm thick, with suitable slots cut to allow for fixing of the bolts or saddles, has been found to be a suitable material for construction of the ladder.
- 2 A typical rubber bush, which has been found to be suitable, is shown in Fig. E-5.
- 3 The value of mass and deflection shall comply with the following: Mass in Kg— 25.0 ± 0.2 , Deflection in mm— 1.5 ± 0.3

Dimensions in millimetres

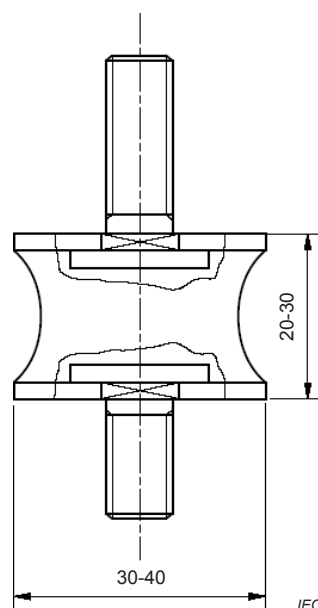


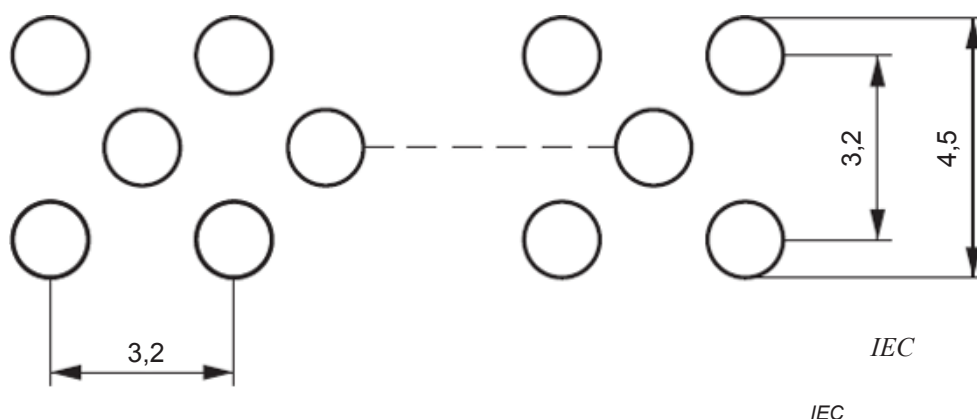
FIG. E-5 TYPICAL RUBBER BUSH FOR SUPPORTING THE TEST LADDER

E-5.3 Source of Heat

E-5.3.1 Burner

The source of heat shall be a ribbon type LPG gas burner with a nominal burner face length of 500 mm (outer distance between outer holes) with a venturi mixer. The nominal burner face width shall be 10 mm. The face of the burner shall have three staggered rows of drilled holes, nominally 1.32 mm in diameter and drilled at centres 3.20 mm from one another, as shown in Fig. E.6.

Dimensions in millimetres
(Dimensions are approximate)



NOTE — Round holes, 1.32 mm in diameter, on centres 3.2 mm from one another, staggered in three rows and centered on the face of the burner. Nominal burner face length 500 mm.

FIG. E-6 — BURNER FACE

A centre-feed burner is recommended.

A row of small holes milled on each side of the burner plate, to serve as pilot holes for keeping the flame burning, is permitted.

E-5.3.2 Flow Meters and Flowrates

Mass flowmeters/controllers shall be used as the means of controlling accurately the input flowrates of fuel and air to the burner.

For the purposes of this test, the air shall have a dew point not higher than 0 °C.

The mass flow rates used for the test shall be as follows:

LPG: (320 ± 13) mg/s ---- for cable diameter exceeding 20 mm

LPG: (160 ± 6) mg/s ---- for cable diameter not exceeding 20 mm

NOTE — This is approximately equivalent to a volume flow rate of (10.0 ± 0.4) litres/min at reference conditions (1 bar and 20 °C).

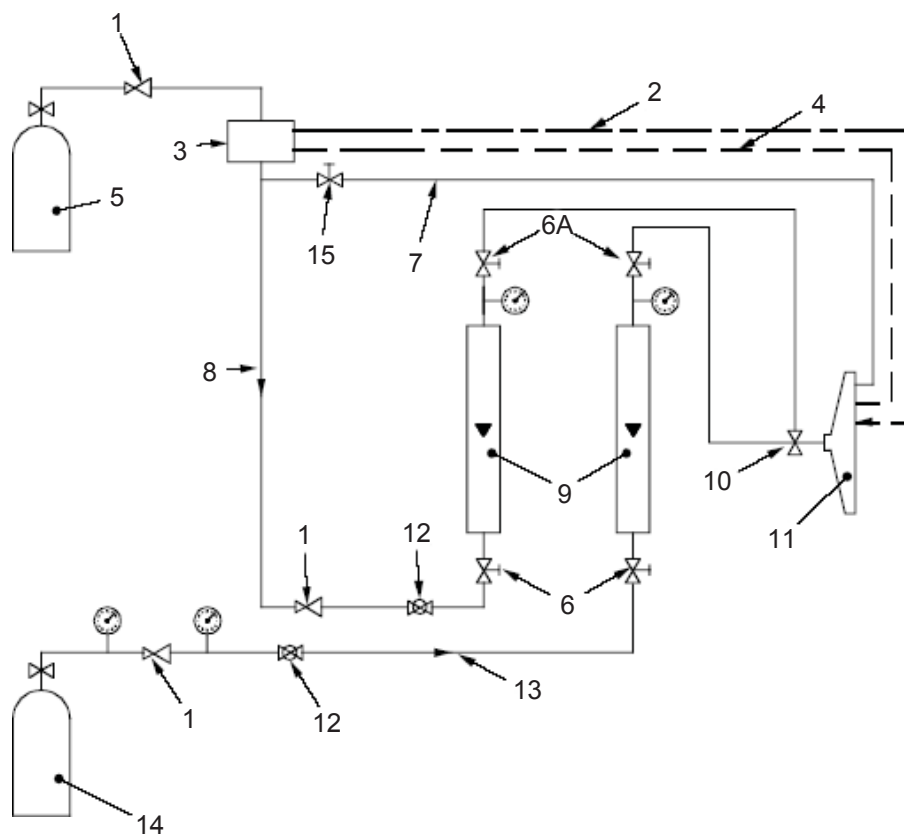
The purity of the LPG is not defined. Industrial grades that contain impurities are allowed provided that the calibration requirements are achieved.

Air: (3270 ± 163) mg/s ---- for cable diameter exceeding 20 mm

Air: (1600 ± 80) mg/s ---- for cable diameter not exceeding 20 mm

NOTE — This is approximately equivalent to a volume flow rate of (160 ± 8) litre/min at reference conditions (1 bar and 20 °C).

A schematic diagram of an example of a burner control system is given in Fig. E-7.



IEC

Key

1	regulator	9	mass flow meters
2	piezoelectric igniter	10	venturi mixer
3	flame failure device	11	burner
4	control thermocouples	12	ball valve
5	LPG cylinder	13	air flow
6	screw valve (6A = alternative position)	14	compressed air cylinder
7	pilot feed	15	screw valve on pilot feed
8	gas flow		

FIG. E-7 SCHEMATIC DIAGRAM OF AN EXAMPLE OF A BURNER CONTROL SYSTEM

E-5.3.3 Verification

The burner and control system shall be subjected to verification following the procedure given in E-5.6

E-5.4 Shock Producing Device

The shock-producing device shall consist of a mild steel round bar (25.0 ± 0.1) mm in diameter and (600 ± 5) mm long. The bar shall be freely pivoted about an axis parallel to the test ladder, which shall be in the same horizontal plane as, and (200 ± 5) mm away from, the upper edge of the ladder. The axis shall divide the bar into two unequal lengths, the longer length being (400 ± 5) mm which shall impact the ladder. The bar shall drop under its own weight from an angle of (60_0^{+5})° to the horizontal to strike the upper edge of the ladder at its mid-point as shown in Fig. E-1; Fig. E.2 and Fig. E-4.

E-5.5 Water Jet Device

The water jet device comprising a 6.3 mm hose nozzle mounted above the test specimen with the test ladder at an angle of (45 ± 5)° to the vertical and at a distance of (500 ± 25) mm from the distance from the center point of the test specimen. The nozzle shall be secured in such a way that the water jet strikes the test specimen at the center point as shown in Fig. E-8.

The nozzle shall be supplied with water at a flowrate of 12.5 litre/min via an on/off valve. The flowrate shall be measured by a volumetric method prior to the test

and the water supply adjusted if necessary. The water supply pipe to be fitted with an in line flow meter so that the water flow rate can be monitored during the test.

E-5.6 Test Wall Equipped with Thermocouples for Verification of the Source of Heat

The flame temperature shall be measured using two 1.5 mm mineral insulated, stainless steel sheathed thermocouples type K in conformance with IEC 60584-1, mounted on the test wall as shown in Fig. E-9. The thermocouple tips shall be (10.0 ± 1.0) mm in front of the test wall. The horizontal line of the thermocouples shall be (100 ± 10) mm above the bottom of the wall. The wall shall consist of a board of heat-resistant, non-combustible and non-metallic material (900 ± 100) mm long, (300 ± 50) mm high and (10 ± 2) mm thick.

E-5.6.1 Procedure

Position the burner 100 mm to 120 mm horizontally from the thermocouple (H) and 40 mm to 60 mm vertically below the centre line of the thermocouples (V) as shown in Fig. E-3.

Ignite the burner and adjust the gas and air supplies to those given in E-5.3.

Monitor the temperature as recorded by the thermocouples over a period of 10 min to ensure conditions are stable.

Dimensions in millimetres

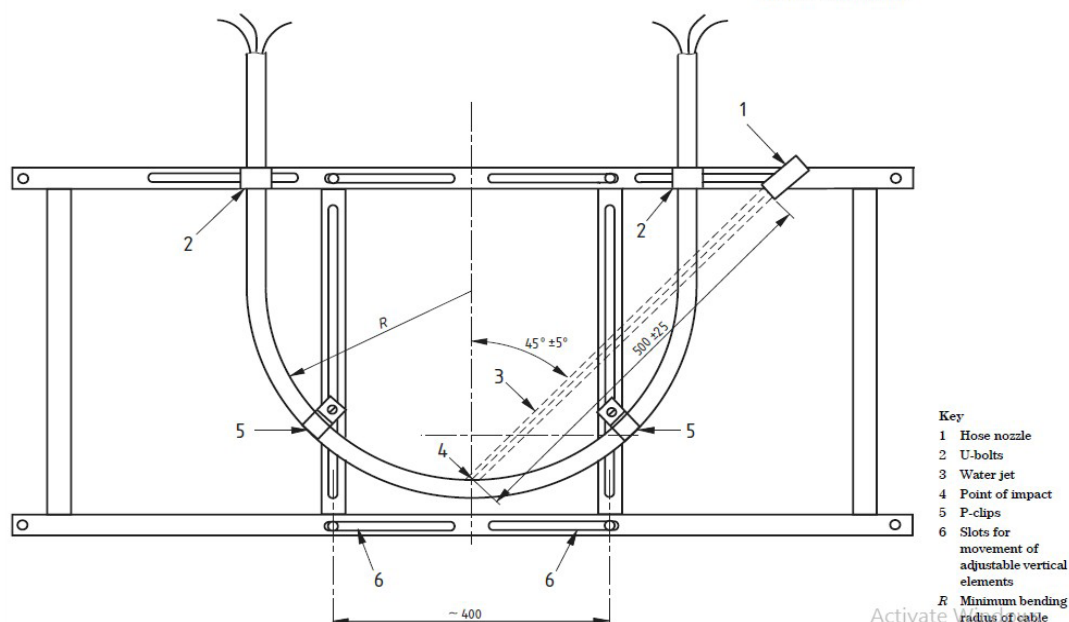
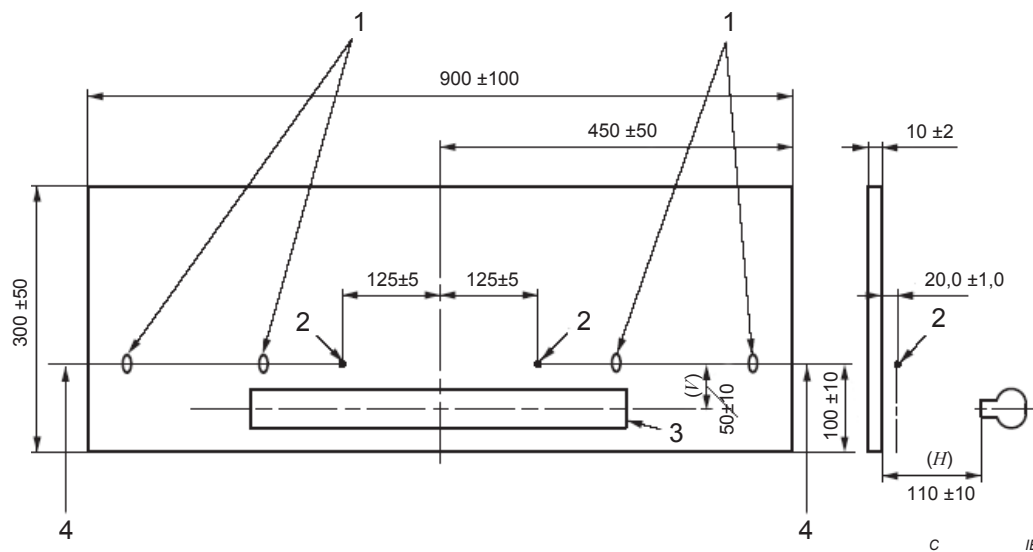


FIG. E-8 – WATER JET DEVICE ARRANGEMENT

Dimensions in millimetres



Key

- | | |
|-----|--|
| 1 | thermocouple supports |
| 2 | thermocouple tip |
| 3 | burner |
| 4 | 1.5 mm type K sheathed thermocouples |
| H | horizontal distance of thermocouple tip from burner face |
| V | vertical distance of thermocouple tip from centre line of burner |

FIG. E-9 TEMPERATURE MEASURING ARRANGEMENT

E-5.6.2 Evaluation

The verification procedure shall be considered satisfactory if the arithmetic mean of the averaged readings for each of the two thermocouples over the 10 min falls within the requirement of **E-7.6**, **E-7.7** and **E-7.8** accordingly. The difference of the averaged readings for each of the two thermocouples over the 10 min period does not exceed 40 °C.

At least one measurement shall be made every 30 s in order to obtain the average.

The actual method of obtaining the average thermocouple reading over the period is not specified, but it is recommended that a recorder with averaging facilities is used in order to damp the variability caused by point measurement.

If the verification is not successful, the flow rates shall be altered within the tolerances given in **E-5.3.2** and a further verification carried out.

E-5.6.3 Further Verification

If the verification of **E.5.6.2** is not successful, the distances (H and V) between the burner and the thermocouples shall be altered (within the tolerance given in **E.5.6.2**) and a further verification carried out.

If no successful verification can be achieved within the tolerances given, then the burner system shall be considered as incapable of providing the source of heat required by this standard.

E-5.6.4 Verification Report

The position established for successful verification (of H and V) and the flow rates used shall be recorded.

E-5.7 Continuity Checking Arrangements

During the test, a current for continuity checking shall be passed through all conductors of the test specimen. This shall be provided by a three-phase star connected or single-phase transformer(s) of sufficient capacity to maintain the test voltage up to the maximum leakage current allowable.

This current shall be achieved by connecting, at the other end of the test specimen, a suitable load and an indicating device (for example, lamp) to each conductor, or group of conductors.

NOTES

- 1** Note the fuse characteristics when determining the power rating of the transformer.
- 2** A current of 0.25 A at the test voltage, through each conductor or group of conductors, has been found to be suitable.

E-5.8 Fuses

Fuses used in the test procedure in E.7 shall comply with IEC 60269-3 Fuse System A-D Type DII, 2A. Alternatively, a circuit-breaker with equivalent characteristics may be used.

Where a circuit-breaker is used, its equivalent characteristics shall be demonstrated by reference to the characteristic curve shown in IEC 60269-3.

The test method using fuses shall be the reference method in the case of dispute.

E-6 TEST SPECIMEN

E-6.1 Test Specimen Preparation

For cable whose overall diameter exceeds 20 mm, a cable sample at least 4.5 m long shall be available from the cable length for test. Each individual test specimen to be tested shall consist of a piece of cable, taken from the cable sample, not less than 1 500 mm long with approximately 100 mm of sheath or outer covering removed at each end.

For cable whose overall diameter does not exceed 20 mm, a cable sample at least 3.6 m long shall be available from the cable length for test. Each individual test specimen to be tested shall consist of a piece of cable, taken from the cable sample, not less than 1 200 mm long with approximately 100 mm of sheath or outer covering removed at each end.

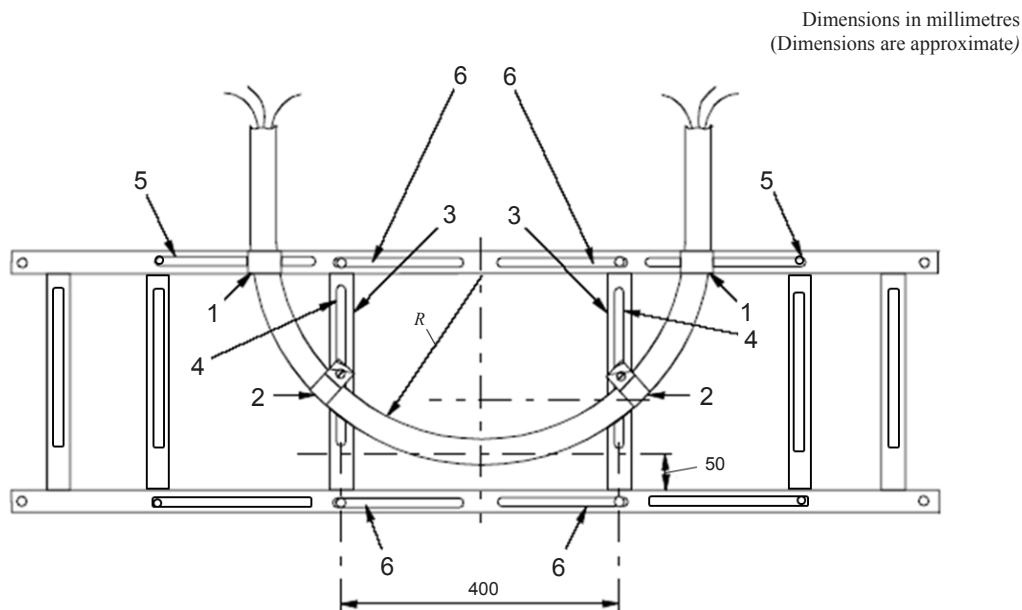
At each end of the test specimen, each conductor shall be suitably prepared for electrical connections, and, if there is more than one conductor, the exposed conductors shall be spread apart to avoid contact with each other.

E-6.2 Test Specimen Mounting (Cable Diameter >20 mm)

The test specimen shall be bent to form an approximate arc of a circle. The internal radius of the bend shall be the manufacturer's declared minimum bending radius in normal use.

The test specimen shall be mounted centrally on the test ladder, as shown in Fig. E-10, using metal clips which shall be earthed. Two U-bolts on the upper horizontal element of the ladder are recommended, but P-clips made of metal strip (20 ± 2) mm wide for cables from 20 mm up to 50 mm in diameter, and (30 ± 3) mm wide for larger cables shall be used on the two central vertical elements. The P-clips shall be formed so as to have approximately the same diameter as the test specimen under test. All clips and bolts shall be earthed.

If the test specimen is too small to be mounted on the central vertical elements when in the position shown in Fig.10, the two central vertical elements shall be equally moved towards the centre so that the specimen may be mounted as shown in Fig. E-11.



Key

- | | | | |
|---|------------------------------|---|---|
| 1 | U-bolt | 5 | slot for U-bolt |
| 2 | P-clip | 6 | slot for movement of adjustable vertical elements |
| 3 | adjustable vertical elements | R | minimum bending radius of cable in normal use |
| 4 | slot for P-clip fixing | | |

FIG. E-10 EXAMPLE OF METHOD OF MOUNTING A LARGER DIAMETER TEST SPECIMEN FOR TEST
(WITH A BENDING RADIUS BETWEEN APPROXIMATELY 200 AND 400 MM)

If the bending radius in normal use is too large to mount the cable as shown in Fig. E-10 on the slots for the U-bolt (key 5 in Fig. E-10), the test specimen shall be mounted as shown in Fig. E-12, using P-clips, which shall be earthed, on the four central vertical elements.

E-6.3 Test Specimen Mounting (Overall Diameter not Exceeding 20 mm)

The test specimen shall be bent to form an appropriate “U” shape. The internal radius of each bend shall be the manufacturer’s declared minimum bending radius in normal use and the overall distance between the vertical portions of the cable shall be (475 ± 10) mm as shown in Fig. E-13.

The test specimen shall be mounted centrally on the wall using metal clips which shall be earthed. The

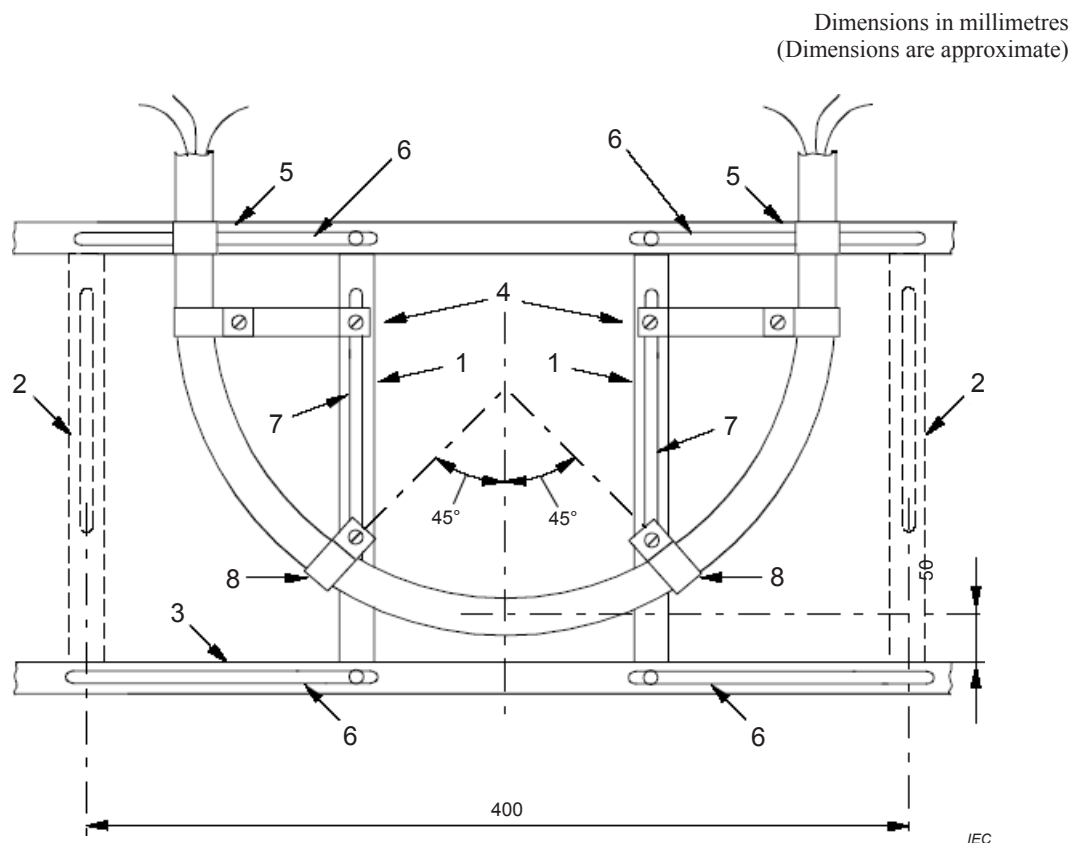
lower edge of the cable shall be (200 ± 10) mm below the top of the test wall. P-clips made of metal strip (10 ± 1) mm wide shall support the test specimen at both ends of the radiused section and in the center as shown in Fig. E-13. The P-clips shall be formed so as to have approximately the same diameter as the cable under test.

E- 7 TEST PROCEDURE

E-7.1 Test Equipment and Arrangement

The test procedure defined in this clause shall be carried out using the apparatus detailed in E.5.

Mount the test specimen on the test ladder and adjust the burner to the correct position relative to the test specimen.

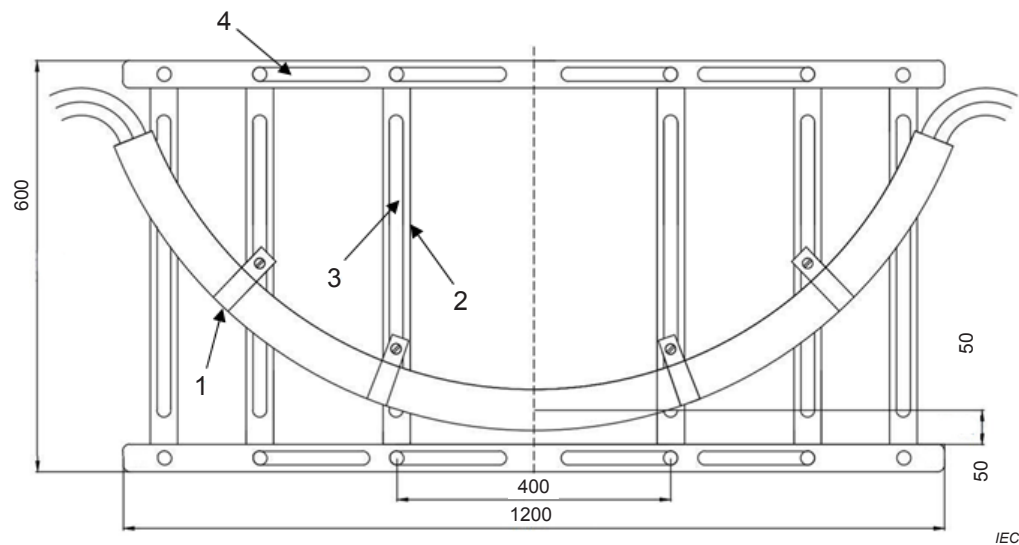


Key

- | | | | |
|---|---|---|---|
| 1 | adjustable position of vertical elements | 5 | U-bolt |
| 2 | normal position of vertical elements | 6 | slot for movement of adjustable vertical elements |
| 3 | lower horizontal element of test ladder | 7 | slot for P-clip fixing |
| 4 | additional clip to maintain cable arc (if required) | 8 | P-clip |

FIG. E-11 DETAILED SECTION OF ADJUSTABLE POSITION OF VERTICAL LADDER ELEMENTS FOR MOUNTING A SMALLER DIAMETER TEST SPECIMEN FOR TEST (WITH A MAXIMUM BENDING RADIUS OF APPROXIMATELY 200 MM)

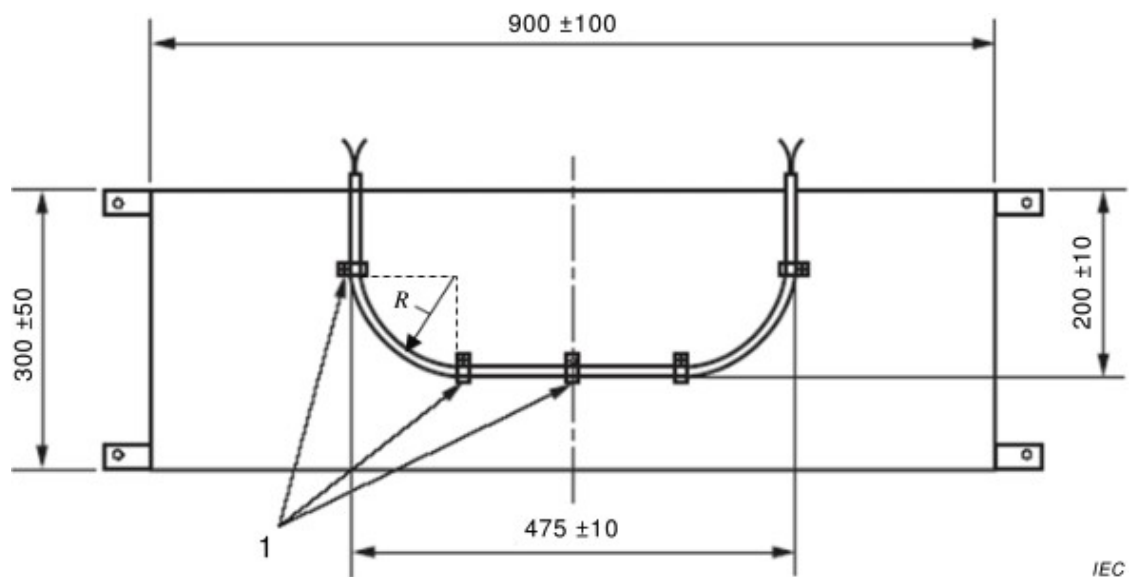
Dimensions in millimetres
(Dimensions are approximate)



Key

- | | | | |
|---|------------------------------|---|---|
| 1 | P-clip | 3 | slot for P-clip fixing |
| 2 | adjustable vertical elements | 4 | slot for movement of adjustable vertical elements |

FIG. E-12 EXAMPLE OF METHOD OF MOUNTING TEST SPECIMEN WITH A BENDING RADIUS IN NORMAL USE LARGER THAN APPROXIMATELY 400 MM



Key

- | | |
|---|--|
| 1 | Metal clip |
| R | Minimum bending radius of cables in normal use |

FIG. E-13 EXAMPLE OF METHOD OF MOUNTING A SAMPLE FOR TEST

The burner face shall be positioned in the test chamber so that it is at least 200 mm above the floor of the chamber, or any solid mounting block, and at least 500 mm from any chamber wall.

By reference to the center point of the test specimen (cable) to be tested, the burner shall be positioned centrally at a horizontal distance of $(H \pm 2)$ mm from the burner face to the center of the test specimen and at a vertical distance of $(V \pm 2)$ mm from the burner horizontal central plane to the center of the test specimen, as shown in Fig. 4.

The exact burner location to be used during cable testing shall be determined using the verification procedure given in E-5.6, where the values of H and V to be used shall be determined.

The burner should be rigidly fixed to the framework during testing so as to prevent movement relative to the test specimen.

E-7.2 Electrical Connections

At the transformer end of the test specimen, earth the neutral conductor, if present, and any protective conductors. Any metal screens, drain wire or metal layer shall be interconnected and earthed. Connect the transformer(s) to the conductors, excluding any conductor which is specifically identified as intended for use as a neutral or a protective conductor, as shown in the circuit diagram in Fig. E-14. Where a metal sheath, armour or screen acts as a neutral or protective conductor, it shall be connected, as shown in the circuit diagram in Fig. E-14, as for a neutral or protective conductor.

For single-, twin- or three-phase conductor cables, connect each phase conductor to a separate phase of the transformer(s) output with a 2 A fuse or circuit-breaker with equivalent characteristics in each phase.

For multi-core cables that have four or more conductors (excluding any neutral or protective conductors), the conductors shall be divided into three roughly equal groups, ensuring that adjacent conductors are, as far as possible, in different groups.

For multi-pair cables, the conductors shall be divided into two equal groups, ensuring that the a-core of each pair is connected to one phase and the b-core of each pair is connected to another phase (L1 and L2 in Fig. E.14). Quads shall be treated as two pairs.

For multi-triple cables, the conductors shall be divided into three equal groups, ensuring that the a-core of each triple is connected to one phase, the b-core of each triple to another phase and the c-core of each triple to the third phase of the transformer (L1, L2 and L3 in Fig. E-14).

Connect the conductors of each group in series and connect each group to a separate phase of the transformer output with a 2 A fuse or circuit-breaker with equivalent characteristics in each phase.

The above test procedure connects the neutral conductor to earth. This may not be appropriate if the cable is designed for use on a system where neutral is not earthed. If required by the cable standard, it is permissible for the neutral conductor to be tested as if it were a phase conductor. Where a metal sheath, armour or screen acts as a neutral conductor, it shall always be connected to earth. Any such variations in methodology should be included in the test report.

For cable constructions not specifically identified above, the test voltage should be applied, as far as is practicable, to ensure that adjacent conductors are connected to different phases.

In certain cases, for example when testing a control cable using a three-phase transformer, it may not be possible to apply a test voltage between conductors and from conductor to earth equal to the rated voltage simultaneously. In such cases, either the test voltage between conductors, or the test voltage from conductor to earth shall be equal to the rated voltage, such that both the test voltage between conductors and the test voltage from conductor to earth is equal to or higher than the rated voltage.

At the end of the test specimen remote from the transformer:

- a) Connect each phase conductor, or group of conductors, to one terminal of the load and indicating device (as described in E-5.7), the other terminal being earthed; and
- b) Connect the neutral conductor and any protective conductor to one terminal of the load and indicating device (as described in E-5.7), the other terminal being connected to L1 (or L2 or L3) at the transformer end (see Fig. E-14).

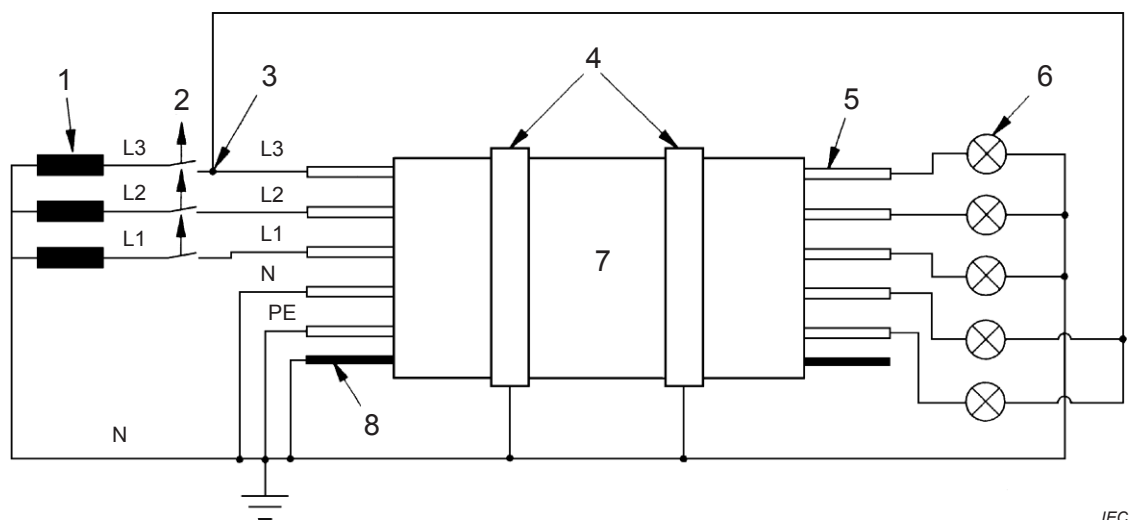
E-7.3 Resistance to Fire Alone (F)

With thermocouple in position, ignite the burner and adjust the LPG and air flowrates until a flame temperature 950 ± 40 °C is steadily registered for at least for 5 min. Continue the flame application for 3 hor as applicable , unless the test specimen fails before the relevant test duration is elapsed.

Immediately after starting the test duration timer, switch on the electricity supply and adjust the voltage to the rated voltage of the cable (subjected to a minimum voltage of 1 000 V ac), that is, the test voltage between conductors shall be equal to the rated voltage between conductors, and the test voltage from conductor to earth shall equal the rated voltage from conductor to earth.

E- 7.4 Resistance to Fire and Water (W)

With thermocouple in position, ignite the burner and adjust the LPG and air flowrates until a flame temperature 650 ± 40 °C is steadily registered for at least for 5 min.



Key

L1, L2, L3	phase conductor (L2, L3 if present)	4	metal clips
PE	protective conductor (if present)	5	test conductor or group
N	neutral conductor (if present)	6	load and indicating device
1	transformer	7	test specimen
2	fuse, 2 A	8	metal screen (if present)
3	L1 or L2 or L3		

FIG. E-14 BASIC CIRCUIT DIAGRAM

Immediately after starting the test duration timer, switch on the electricity supply and adjust the voltage to the rated voltage of the cable (subjected to a minimum voltage of 1 000 V ac), that is, the test voltage between conductors shall be equal to the rated voltage between conductors, and the test voltage from conductor to earth shall be equal to the rated voltage from conductor to earth.

After the flame has been applied for 15 min, activate the water jet device and apply a burst of water for 5 s duration. Sixty seconds after the start of this first burst of water, apply a further burst of water for 5 s duration. Repeat this procedure until a total of 5 bursts of water have been applied. Maintain the test voltage throughout the water drenching phase even if the flame is extinguished by water jet. In such a case of flame getting extinguished, it is advised to stop the LPG supply as a matter of safety.

E- 7.5 Flame and Shock Application(S)

With thermocouple in position ignite the burner and adjust the LPG and air flowrates until a flame temperature 950 ± 40 °C is steadily registered for at least for 5 min.

Immediately after igniting the burner, activate the shock-producing device and start the test duration timer.

The shock-producing device shall impact the ladder after $5 \text{ min} \pm 10 \text{ s}$ from activation and subsequently at $5 \text{ min} \pm 10 \text{ s}$ intervals. After each impact, the impacting bar shall be raised from the test ladder within 20 s after each impact.

Immediately after starting the test duration timer, switch on the electricity supply and adjust the voltage to the rated voltage of the cable (subject to a minimum voltage of 1 000 V AC), that is, the test voltage between conductors shall be equal to the rated voltage between conductors, and the test voltage from conductor to earth shall be equal to the rated voltage from conductor to earth.

The test shall continue for the flame application time for 15 min, unless the test specimen fails before the relevant test duration is elapsed.

E-7.6 Flame, Shock and Water Jet Application (F30)

With thermocouple in position ignite the burner and adjust the LPG and air flow rates until a flame temperature (830 ± 40) °C is steadily registered for atleast for 5 min. Immediately after igniting the burner, activate the shock-producing device and start the test duration timer. The shock-producing device shall impact the ladder after $5 \text{ min} \pm 10 \text{ s}$ from activation and subsequently at $5 \text{ min} \pm 10 \text{ s}$ intervals. After each

impact, the impacting bar shall be raised from the test ladder within 20 s after each impact. Continue the flame application and impact for 30 min.

E-7.6.1 Water Drenching Phase

Five minutes before the end of the flame application with impact phase, activate the water jet device and apply a burst of water for 5 s duration. Sixty seconds after the start of this burst of water, apply a further burst of water for 5 s duration. Repeat this procedure until a total of 5 bursts of water have been applied. Maintain the test voltage throughout the water drenching phase even if the flame is extinguished by the flame.

E-7.6.2 Electrification

Immediately after starting the test duration timer, switch on the electricity supply and adjust the voltage to the rated voltage of the cable (subject to a minimum voltage of 1 000 V a.c.), that is the test voltage between conductors shall be equal to the rated voltage between conductors, and the test voltage from conductor to earth shall be equal to the rated voltage from conductor to earth.

E-7.7 Flame, Shock and Water Jet Application (F60)

Follow the test procedure mentioned at E-7.6 and continue the flame application and impact for 60 min.

E-7.8 Flame, Shock and Water Jet Application (F120)

Follow the test procedure mentioned at E-7.6 and continue the flame application and impact for 120 min.

E-8 PERFORMANCE REQUIREMENTS

E-8.1 Acceptance Criteria

With reference to the test procedure given in E.7, the cable possesses the characteristics for providing circuit integrity so long as during the course of the test:

- a) the voltage is maintained, that is, no fuse fails or circuit-breaker is interrupted, and
- b) a conductor does not rupture, that is, the lamp is not extinguished.

Failure by either one of the criteria listed shall be sufficient to show a failure for that cable.

E-8.2 Re-test Procedure

In the event of a failure, as judged by the requirements of the relevant standard, two further test specimens, taken from the same cable sample, shall be tested. If both comply, the test shall be deemed successful.

ANNEX F

(Table 1 and Table 2)

ASSESSMENT OF HALOGENS

F-1 REQUIREMENTS

F-1.1 The insulation and sheath shall meet the type test requirements as given in the Table 11:

F-1.2 The material shall be tested as per given sequence as per the Table 12.

Table 11 Type Test Requirements for Insulation and Sheath

(Clause F-1.1)

Sl No.	Test Method	Measure	Requirements
(1)	(2)	(3)	(4)
i)	See F-2	pH and conductivity	$pH \geq 4.3$ and conductivity $\leq 10 \mu S/mm$
ii)	IS 10810 (Part 59)	Chlorine and bromine content expressed as content of HCL	≤ 0.5 percent
iii)	See F-3	Presence of fluorine	a) If negative, stop further test. b) If positive, test as per 3b.
iv)	See F-4	Fluorine content	≤ 0.1 percent

Table 12 Sequence for the Testing of Materials
(Clause F-1.2)

SI No.	Test Method	Measure	Requirements	Outcome
Step 0	See F-3	Halogen: Fluorine, chlorine and bromine	Negative value	If negative stop test – material accepted. If positive go to step 1
		pH	pH < 4.3	Reject the material
			pH ≥ 4.3	Evaluate conductivity
Step 1	See F-2	Conductivity	≤ 2.5 μS/mm	Accept no further testing required
			> 10 μS/mm	Reject material
			> 2.5 ≤ 10 μS/mm	Chlorine bromine determination as per See F-3
Step 2	IS 10810 (Part 59)	Chlorine and bromine content expressed as hydrochloric acid (HCl)	> 0.5 percent	Reject material
			≤ 0.5 percent	See F-4
	See F-4	Fluorine content	> 0.1 percent	Reject material
			≤ 0.1 percent	Accept material

F-2 DETERMINATION OF DEGREE OF ACIDITY OF COMBUSTION GASES FOR MATERIAL BY MEASURING PH AND CONDUCTIVITY

F-2.1 Test Method Principle

The material under test shall be heated in a stream of dry air. The evolved gases shall be trapped by bubbling through wash bottles filled with distilled or demineralized water.

The acidity of the resulting solution shall be assessed by determination of its pH value. The conductivity of the solution shall also be determined.

F-2.2 Test Apparatus

F-2.2.1 General

The apparatus is shown in Fig. F-1 to Fig. F-5.

The assembly of the components which constitute the test apparatus shall be leak-tight. The connecting distances between the quartz glass tube and the first bottle and between subsequent bottles shall be as short as possible. Glass or silicone rubber tubing shall be used for these connections.

NOTES

1 At the exit side of the quartz glass tube, as close to the end as possible, it is permitted to place a plug of silica wool to aid collection of condensates.

2 A third empty bottle, of the same size as the gas washing bottles, placed before the gas washing bottles may be used to improve safety, that is, to prevent suck back of water into the quartz glass tube.

F-2.2.2 Tube Furnace

The length of the heating zone of the furnace shall be within the range 480 mm to 620 mm and its inside diameter shall be within the range 38 mm to 62 mm. It shall be equipped with an adjustable electrical heating system.

F-2.2.3 Quartz Glass Tube

For the test, a quartz glass tube shall be introduced into the tube furnace. The tube shall be approximately concentric to the furnace. It shall be resistant to the action of corrosive gases.

The inside diameter of the tube shall be within the range 30 mm to 46 mm. The tube shall protrude on the entrance side of the furnace by a length of between 60 mm to 200 mm, and on the exit side by between 60 mm to 100 mm. The initial clearance shall allow for thermal expansion. For the purposes of measurement of the protrusion distances, the tube shall be regarded as that part of essentially constant diameter.

NOTE — The outer diameter of the tube should be chosen with due regard to the inside diameter of the tube furnace.

Prior to each test the tube shall be cleaned throughout its length by being calcined at approximately 950 °C.

F-2.2.4 Combustion Boats

The combustion boat shall be made of porcelain, fused quartz or soapstone and shall have the following dimensions:

- external length: within the range 45 mm to 100 mm;
- external width: within the range 12 mm to 30 mm; and
- internal depth: within the range 5 mm to 10 mm.

NOTE — The dimensions of the boat should be chosen with due regard to the inside diameter of the quartz tube.

The preferred method for insertion of the combustion boat into the quartz glass tube is shown in Fig. F-1.

Prior to each test, the combustion boat shall be washed and calcined in a muffle furnace at approximately 950 °C for 4 h after which it shall be introduced into a desiccator and cooled to ambient temperature. The combustion boat shall then be weighed to an accuracy of 0.1 mg until two identical consecutive weights are obtained. This weight m_1 shall be recorded.

F-2.2.5 Bubbling Devices for Gases

At the exit of the quartz glass tube, the evolved gases shall be trapped by bubbling through two wash bottles (see Fig. F-2), each containing approximately 450 ml of distilled or demineralized water of a purity at least grade 3 in accordance with IS 1070.

The pH value of the water shall be 6.5 ± 1 , and the conductivity less than $0.5 \mu\text{S/mm}$.

A magnetic stirrer shall be introduced in the first gas washing bottle to get a good swirling motion and an effective absorption of the combustion gases. The tubes into the wash bottles shall have a maximum internal diameter at their tip of 5 mm in order to aid absorption.

The height of the liquid above the end of the tube shall be (110 ± 10) mm in each bottle.

NOTE — Use of a standard laboratory glass bottle of internal diameter approximately 75 mm will enable this requirement to be met.

F-2.2.6 Air Supply System

The gas used for combustion shall be air.

The flow rate of air introduced into the quartz tube shall be adjusted according to the actual internal cross-sectional area of the tube, such that the speed of air flowing across the sample is approximately $20 \text{ ml/mm}^2/\text{h}$.

The speed of air shall be regulated by reference to the flow rate of air. The flow rate of air shall be $(0.0157 \times D^2) \text{ l/h}$ with a tolerance of ± 10 percent.

NOTE — The derivation of the flow rate of air from the speed of air is:

$$\rho = V \times \frac{\pi D^2}{4}$$

where

D = internal diameter of the tube (mm);

ρ = flow rate of air (ml/h); and

V = speed of air (ml/mm²/h).

The air supply shall be adjusted and controlled by a needle valve, and the flow rate monitored by a flowmeter of the appropriate range.

The air supplied shall be selected from one of the following methods:

a) *Method 1*

This method uses synthetic air or compressed air from a bottle. The air shall be introduced on the inlet side of the quartz glass tube (see Fig. F-3).

b) *Method 2*

This method uses a laboratory compressed air supply. Air shall be introduced on the inlet side of the quartz glass tube and shall be filtered and dried (see Fig. F-4).

c) *Method 3*

This method uses the ambient air of the laboratory. The air shall be filtered and dried. In this case, the mixture

of air and combustion gas shall be sucked by a pump (see Fig. F-5).

F-2.2.7 Analytical Balance

The balance shall have a precision of $\pm 0.1 \text{ mg}$.

F-2.2.8 Laboratory Glassware

For pH and conductivity determination, the following laboratory glassware shall be available:

one mark volumetric flask in accordance of IS 915 with 1 000 ml capacity.

F-2.2.9 pH Meter

The pH meter shall have a precision of ± 0.02 and shall be equipped with a pH electrode.

F-2.2.10 Conductivity Measuring Device

The conductivity measuring device shall have a range of $10^{-1} \mu\text{S/mm}$ to $10^{+2} \mu\text{S/mm}$ and shall be equipped with an electrode.

F-2.3 Test Specimen**F-2.3.1 General**

Three test specimens for the general method, or two for the simplified method, each consisting of $(1\ 000 \pm 5) \text{ mg}$ of the material to be tested, shall be prepared. Each test specimen shall be taken from a sample representative of the material. Each test specimen shall be cut into a number of smaller pieces.

NOTE — Pieces with a maximum dimension of 3 mm have been found to be suitable.

F-2.3.2 Conditioning of Specimen

The prepared test specimens shall be stored for at least 16 h at a temperature of $(23 \pm 2) ^\circ\text{C}$ and a relative humidity of (50 ± 5) percent.

F-2.4 Test Procedure**F-2.4.1 General**

The test procedure and determination of pH value and conductivity value shall be carried out on each test specimen.

F-2.4.2 Test Apparatus and Arrangement

The test procedure defined in this clause shall be carried out using the apparatus detailed in F-5.

F-2.4.3 Heating Procedure

The air flow shall be adjusted by means of a needle valve to the value specified in F-2.2.6 and shall be kept constant during the test.

The temperature shall be measured by a thermocouple suitably protected against corrosion and placed inside the quartz glass tube. The heating system shall be adjusted such that the temperature at the designated position for the boat shall be not less than $935 ^\circ\text{C}$ and

not more than 965 °C. The temperature at a position 300 mm from the designated position in the direction of the air flow shall be not less than 900 °C.

The boat containing the test specimen shall be quickly inserted into the heating zone of the tube to the designated position determined by the thermocouple measurement and the timer shall be started. The combustion boat shall be placed in such a way that the distance between the boat and the exit end of the effective heating zone is at least 300 mm. The effective heating zone is that zone where a temperature of not less than 900 °C has been determined by the thermocouple measurement.

The combustion procedure, under the air flow condition, shall be continued for (30 ± 1) min in the furnace.

WARNING — The operator should take precautions, for example, the wearing of eye protection and suitable protective clothing, because certain materials ignite quickly, and can cause “blow back” of hot gases. Care should also be taken to avoid over-pressurization of the system, and to allow for venting of exhaust gases. Guidance on the avoidance of “blow back” is given in Note 2 of **F-2.2.1**.

F-2.4.4 Washing Procedure

Following the heating procedure, all the bottles used shall be disconnected, and the contents washed into a 1 000 ml volumetric flask. Using water with the properties given in **F-2.2.5**, the bottles, the connecting links and, after cooling, the end of the quartz glass tube including the silica wool (if used) shall also be washed into the flask, and the contents made up to 1 000 ml.

F-2.5 Determination of the pH Value and Conductivity

The pH shall be measured using a pH meter calibrated as proposed by the instrument supplier.

The pH value of the solution shall be determined at (25 ± 1) °C in accordance with the test procedures as prescribed by the supplier of the measuring instrument.

Conductivity value measurements shall also be performed at (25 ± 1) °C in accordance with the test procedures as prescribed by the supplier of the conductivity measuring instrument.

The pH value and conductivity value shall preferably be read by using automatic temperature compensation. If such a facility is not available, the values shall be read when the temperature of the solution is at (25 ± 1) °C.

NOTE — Automatic temperature compensation is usually an integral feature of the pH and conductivity measuring instruments.

F-2.6 Evaluation of the Test Results

From the two test determinations undertaken, the sample shall be considered to have met the performance requirement if both pH values are greater than or equal to the specified value and both conductivity values are less than or equal to the specified value.

F-3 DETERMINATION OF HALOGENS — ELEMENTAL TEST

WARNING — Owing to its potentially hazardous nature the fusion operation should be carried out in a fume cabinet, using safety screen.

F-3.1 Equipment

- Bunsen burner;
- Glass test tubes of approximately 50 mm × 10 mm;
- Test tube holder;
- Evaporating basin/mortar;
- Wire gauge;
- Funnel; and
- Filter paper.

F-3.2 Materials

- Sample;
- Sodium metal;
- Nitric acid (5 percent);
- Aqueous silver nitrate (5 percent);
- Freshly prepared zirconium-alizarin red S reagent;
- Glacial acetic acid; and
- pH papers.

F-3.3 Procedure

F-3.3.1 Sodium Fusion

Place 200 to 250 mg of the sample into the bottom of a small soda glass test tube. Add 10 ml of de-ionized water to the evaporating basin and place this in the fume cupboard behind the safety screen. Whilst holding the test tube firmly with the test tube holder at an angle of 45° to 60° to the vertical, introduce a piece of freshly cut, clean sodium in size of a small pea (200 to 250 mg) into the mouth of the test tube without allowing it to come into contact with the sample directly. With the safety screen in place, heat the sodium gently until it melts and runs down on to the sample leading to vigorous reaction when the molten sodium reaches the sample in case of presence of halogen. Heat the test tube gently for about a minute, then more strongly until the lower 20 mm of the test tube glows red hot. Plunge the red hot tube into the water in the evaporating basin, immediately placing the gauze on the top, to prevent the loss of material when tube shatters on contact with water. Allow any unreacted sodium to react before grinding up the solution and glass. Filter and separate the filtrate into two equal portions.

F-3.4 Determination of Presence of Chlorine and Bromine

To the first portion of the filtrate, add sufficient nitric acid to make the solution acidic. Boil this total volume till reduced by half, to remove any hydrogen cyanide

(HCN) or hydrogen sulfide (H₂S), if present, which would interfere with the test. Add 1 ml of silver nitrate solution a white or yellowish precipitate indicates the presence of halogen (Cl, Br), in the original sample (if the liquor is decanted and the precipitate is white and readily soluble in dilute ammonia then chloride is present).

F-3.5 Determination of Presence of Fluorine

To the second portion of the filtrate, acidify with glacial acetic acid. Boil this solution until its total volume is reduced to half.

Add two to three drops of freshly prepared zirconium lake reagent (equal volume of):

- Alizarin solution: Prepared by mixing 0.05 gm alizarin Red-S in 50 ml distilled water.
- Zirconium solution: 0.05 gm zirconium nitrate in 10 ml concentrated hydrochloric acid (HCL) diluted with 50 ml of distilled water.

Heat at 40 °C for one hour. The presence of fluoride is indicated by the red/pink colouration being bleached to yellow.

F-4 DETERMINATION OF LOW LEVELS OFFLUORINE

F-4.1 Principle

F-4.1.1 General

The sample is burnt in an oxygen flask, and the resulting solution is used to measure the fluorine content. The fluorine content may be measured using either of the following methods:

- Method A — A fluoride ion selective electrode, or
- Method B — Colourimetrically, by formation of the blue-red oligomer fluorine blue complex.

F-4.1.2 Apparatus

- Oxygen flask;
- Pipettes; and
- Volumetric flasks.

NOTE — All apparatus used in the fluorine determination should be made of polycarbonate or polypropylene, as fluoride ions react with glassware.

For method A, ion selective electrode (fluoride) with suitable millivolt meter and for method B, visible spectrophotometer.

F-4.1.3 Reagents

- Method A: electrode filling solution — Buffer solution as recommended by electrode manufacturer.

- Method B: alizarin fluorine blue reagent — Dissolve 2.5 galizarin fluorine blue complex in 15 ml 2 propanol plus 35 ml water. Filter before use.
- Standard fluoride solution prepared from sodium fluoride.
- Dodecanol.
- 0.5 M Sodium hydroxide solution.

F-4.2 Procedure

F-4.2.1 General

Place an accurately weighed sample of material (25 mg-30 mg) in a 1 l oxygen flask using 2 to 3 drops of dodecanol on the sample to assist burning. Add 5 ml of 0.5 M sodium hydroxide solution as absorbant. Burn the sample and allow mist to settle. Transfer the contents of the flask with minimum washing to a 50 ml volumetric flask and proceed with method A or B.

F-4.2.2 Method A — Ion Selective Electrode Method Fluoride

Add 5 ml of recommended/buffer reagent to the sample solution and washings, and make up to the mark. Construct a calibration curve for the fluoride ion electrode according to the manufacturer's instructions. Measure the fluoride concentration of the sample solution and calculate the percentage of fluorine in the sample.

F-4.2.3 Method B — Alizarin Fluorine Blue Method

Add 5 ml alizarin fluorine blue reagent to the sample solution and washings and make up to the mark. Allow to stand for the colour to develop. Measure the absorbance of the solution at 630 nm using a 1 cm cell with water as blank.

Construct a calibration curve by suitably diluting the standard fluoride solution to give concentrations in the range 0 µg/ml to 2 µg/ml. Also measure the absorbance of a reagent blank using reagent and water only. Calculate the fluorine concentration in the sample.

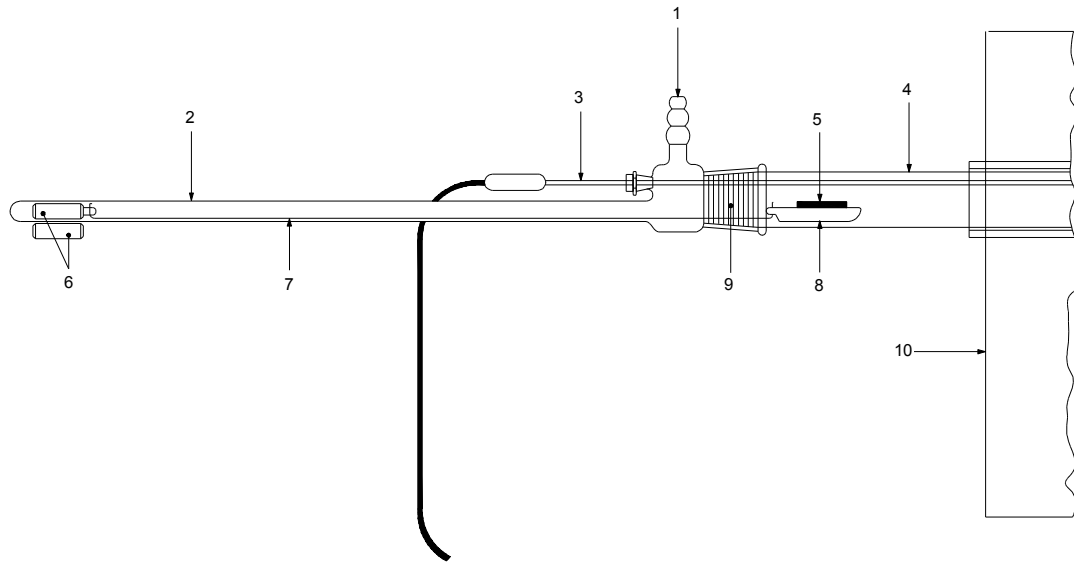
F-4.2.4 Using this method, it is estimated that fluorine levels with values greater than 0.02 percent can be detected.

In order to determine total halogen content of the material under test, the methods described in F-4.3 both a) and b) shall be used.

F-4.3 Acid Gas Generation

Tests shall be performed in accordance with the method specified in IS 10810 (Part 59).

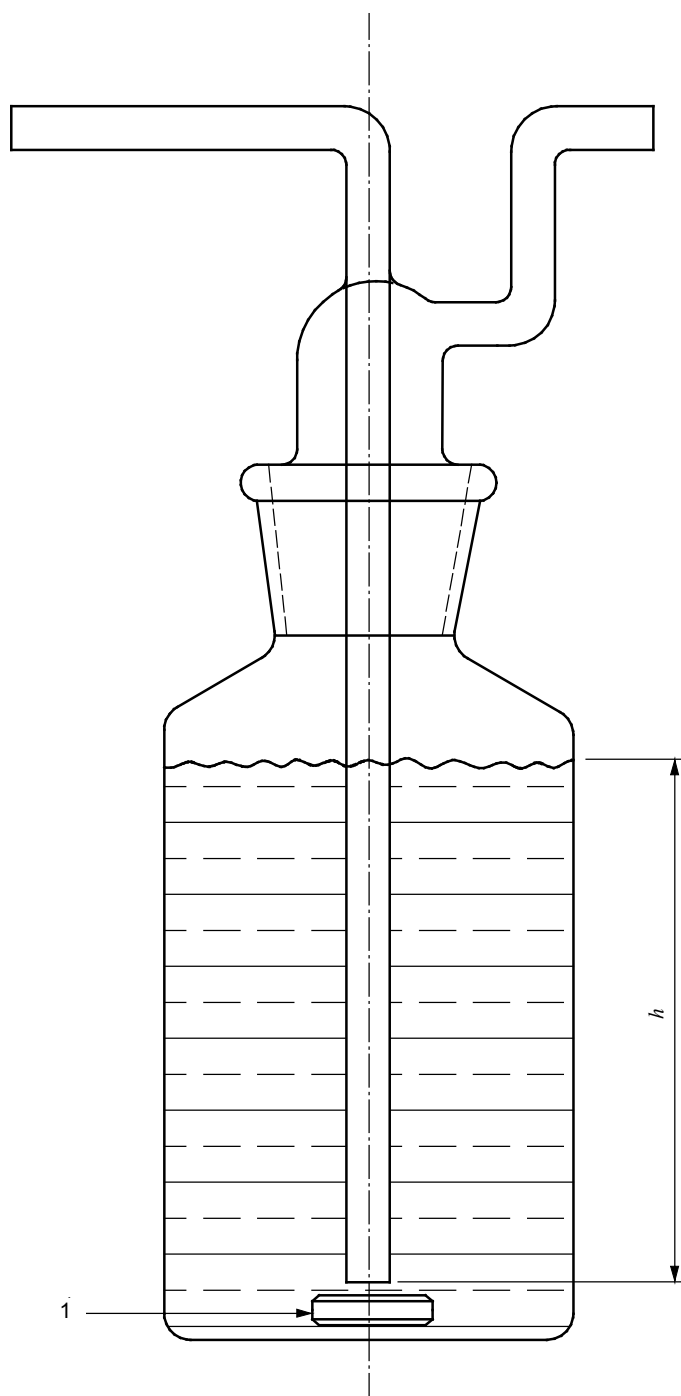
Tests shall be performed in accordance with the method specified in F-2.



Key

- | | | | |
|---|---|----|---|
| 1 | Synthetic air or compressed air, filtered and dried | 6 | Bar magnets |
| 2 | Glass tube | 7 | Platinum wire |
| 3 | Thermocouple | 8 | Combustion boat |
| 4 | Quartz glass tube | 9 | Standard ground joint, size in correlation to the diameter of the quartz glass tube |
| 5 | Test specimen | 10 | Furnace |

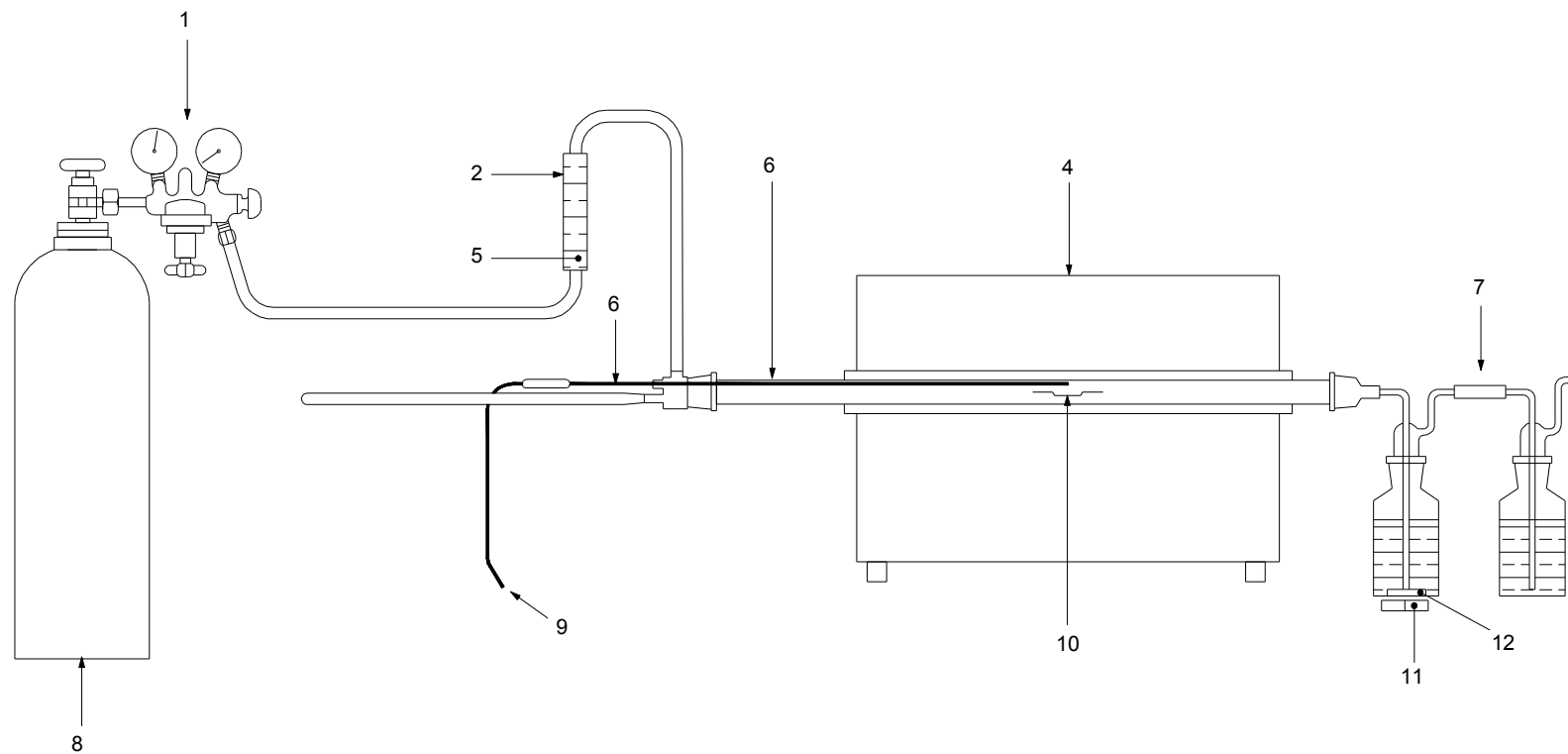
FIG. F-1 DEVICE FOR INSERTING COMBUSTION BOAT AND TEST SPECIMEN



Key

1 Magnetic stirring bar h 100 mm to 120 mm

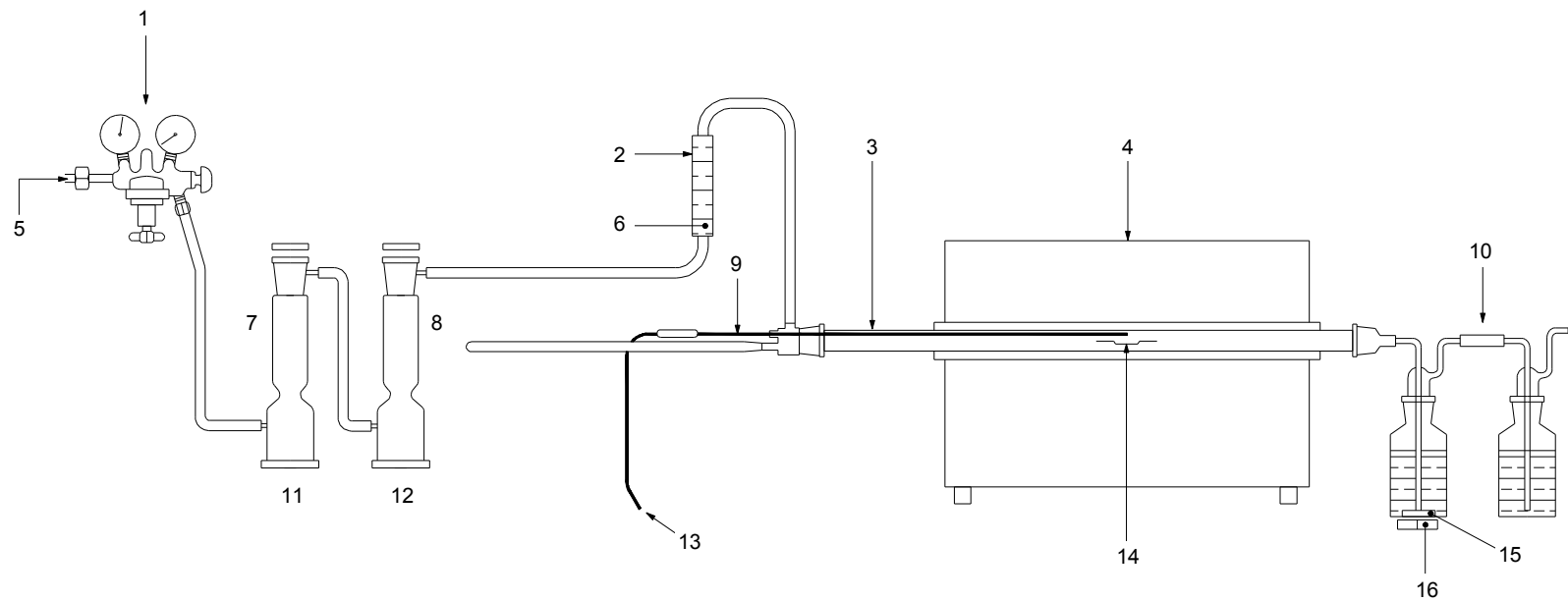
FIG. F-2 EXAMPLE OF A GAS WASHING BOTTLE



Key

- | | |
|---------------------------|---|
| 1 Pressure reducing valve | 7 Gas washing bottles |
| 2 Flow meter | 8 Synthetic air |
| 3 Quartz glass tube | 9 Device for inserting combustion boat containing test specimen |
| 4 Furnace | 10 Combustion boat containing test specimen |
| 5 Needle valve | 11 Magnetic stirrer |
| 6 Thermocouple | 12 Magnetic stirring bar |

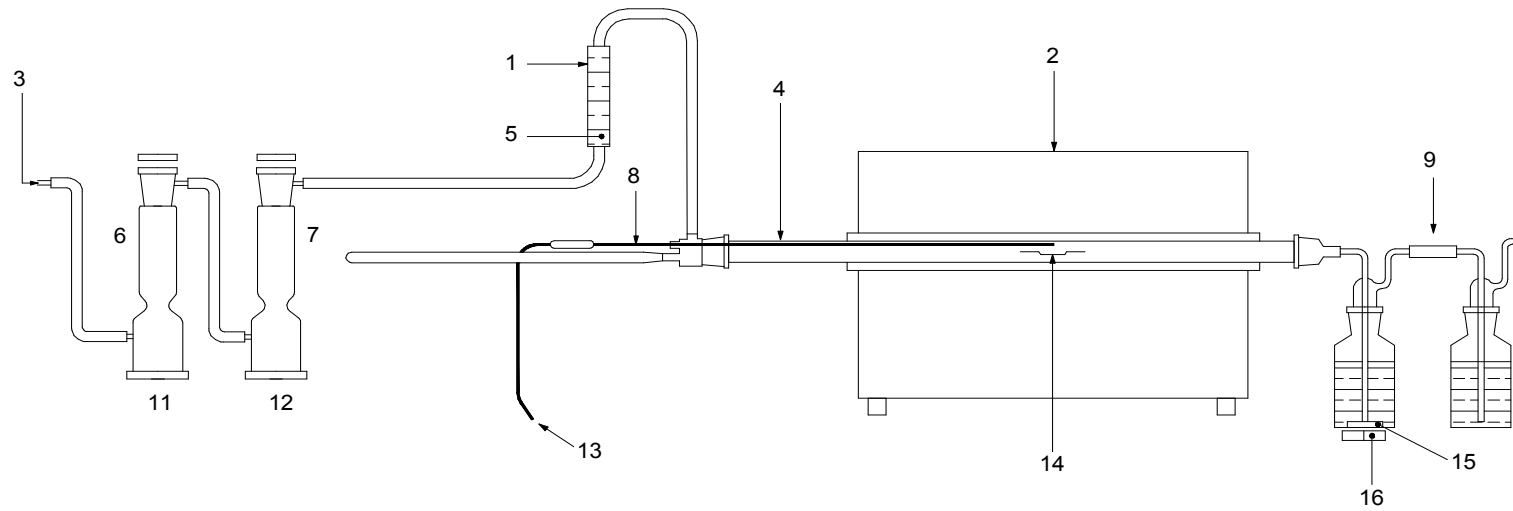
FIG. F-3 TEST APPARATUS: METHOD 1 – USE OF SYNTHETIC OR COMPRESSED AIR FROM A BOTTLE



Key

1	Pressure reducing valve	7	Activated charcoal	13	Device for inserting combustion boat containing test specimen
2	Flow meter	8	Silica gel	14	Combustion boat containing test specimen
3	Quartz glass tube	9	Thermocouple	15	Magnetic stirring bar
4	Furnace	10	Gas washing bottles	16	Magnetic stirrer
5	Compressed air	11	Air filtering		
6	Needle valve	12	Air drying		

FIG. F-4 TEST APPARATUS: METHOD 2 – USE OF LABORATORY COMPRESSED AIR SUPPLY



Key

1	Flow meter	7	Silica gel	13	Device for inserting combustion boat containing test specimen
2	Furnace	8	Thermocouple	14	Combustion boat containing test specimen
3	Ambient air	9	Gas washing bottles	15	Magnetic stirring bar
4	Quartz glass tube	10	Suction pump	16	Magnetic stirrer
5	Needle valve	11	Air filtering		
6	Activated charcoal	12	Air drying		

FIG. F-5 TEST APPARATUS: METHOD 3 – USE OF AMBIENT AIR SUCKED BY MEANS OF A SUCTION PUMP

ANNEX G

(Foreword)

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